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Preliminary Data Summary for the Solvent Recycling Industry

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This document is one of a series of Preliminary Data Summaries prepared by the Office of Water Regulations and Standards of the U. S. Environmental Protection Agency. The Summaries contain engineering, economic and environmental data that pertain to whether industrial facilities in various industries discharge pollutants in their wastewaters and whether the EPA should pursue regulations to control such discharges. The summaries were prepared in order to allow EPA to respond to the mandate of Section 304(m) of the Clean Water Act, which requires the Agency to develop plans to regulate industrial categories that contribute to pollution of the Nation's surface waters. Summaries for categories already subject to rulemaking were developed for comparison purposes, and contain only the minimum amount of data needed to provide some perspective on the relative magnitude of the pollution problems created across the categories.

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PRELIMINARY DATA SUMMARY

FOR THE

SOLVENT RECYCLING INDUSTRY

Office of Water Regulations and Standards
Office of Water
United States Environmental Protection Agency
Washington, D.C.

September 1989

PREFACE

This is one of a series of Preliminary Data Summaries prepared by the Office of Water Regulations and Standards of the U.S. Environmental Protection Agency. The Summaries contain engineering, economic and environmental data that pertain to question as to whether the industrial facilities in various industries discharge pollutants in their wastewaters and whether the EPA should pursue regulations to control such discharges. The summaries were prepared in order to allow EPA to respond to the mandate of section 304(m) of the Clean Water Act, which requires the Agency to develop plans to regulate industrial categories that contribute to pollution of the Nation's surface waters.

The Summaries vary in terms of the amount and nature of the data presented. This variation reflects several factors, including the overall size of the category (number of dischargers), the amount of sampling and analytical work performed by EPA in developing the Summary, the amount of relevant secondary data that exists for the various categories, whether the industry had been the subject of previous studies (by EPA or other parties), and whether or not the Agency was already committed to a regulation for the industry. With respect to the last factor, the pattern is for categories that are already the subject of regulatory activity (e.g., Pesticides, Pulp and Paper) to have relatively short Summaries. This is because the Summaries are intended primarily to assist EPA management in designating industry categories for rulemaking. Summaries for categories already subject to rulemaking were developed for comparison purposes, and contain only the minimal amount of data needed to provide some perspective on the relative magnitude of the pollution problems created across the categories.

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Additional copies of this document may be obtained by writing to the following address:

Industrial Technology Division (WH-552)
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, D.C. 20460

Telephone (202) 382-7131

TABLE OF CONTENTS

Section			Page
1.	FOREWORD		1
2.	SUMMARY		2
3.	INTRODUCTION		6
	3.1	Purpose and Authority	6
	3.2	Regulatory Overview	7
		3.2.1 Resource Conservation and Recovery Act	7
		3.2.2 Domestic Sewage Exclusion	7
		3.2.3 Land Disposal Restrictions	10
		3.2.4 Accumulation Time Exemption	10
	3.3	Overview of the Industry	10
	3.4	Data and Information Gathering	11
		3.4.1 State and Local Data	11
		3.4.2 Trade Associations	12
		3.4.3 Telephone Contacts	12
		3.4.4 Literature Review	12
		3.4.5 Facility Site Visits	13
4.	DESCRIPTION OF THE INDUSTRY		14
	4.1	Industry Profile	14
	4.2	Solvent Recycling Processes	18
		4.2.1 Solvent Storage Handling	18
		4.2.2 Initial Treatment	18
		4.2.3 Distillation	18
		4.2.4 Purification	21
	4.3	Solvent Usage and Spent Solvent Generation	21
	4.4	Industry Subcategorization	23
	4.5	Potential for Industry Growth	24
	4.6	Financial Characteristics of Commercial Facilities	27
	4.7	Summary	28
5.	WATER USES AND WASTEWATER CHARACTERIZATION		29
	5.1	Pollutant Analysis, Recovery, and Quantification	29
	5.2	Water Usage	30
	5.3	Wastewater Sources	30
		5.3.1 Process Wastewater	31
		5.3.2 Cooling and Miscellaneous Wastewater	41
	5.4	Residuals Disposal	43
	5.5	Summary	46

TABLE OF CONTENTS (Continued)

Section		Page
6.	CONTROL AND TREATMENT TECHNOLOGY	53
	6.1 Zero Discharge Methods.	53
	6.2 In-Plant Wastewater Control	53
	6.3 Wastewater Treatment.	53
	6.4 Best Available Demonstrated Technology.	54
	6.5 Summary	58
7.	COST OF WASTEWATER CONTROL AND TREATMENT	60
	7.1 Process Wastewater.	60
	7.2 Cooling and Miscellaneous Wastewater.	61
	7.3 Economic Assessment and Cost-Effectiveness.	62
	7.3.1 Economic Assessment.	62
	7.3.2 Cost-Effectiveness	64
	7.4 Summary	68
8.	ENVIRONMENTAL ASSESSMENT	70
	8.1 Methodology Used to Estimate Human Health and Aquatic Life Water Quality Impacts.	70
	8.1.1 Direct Discharge Analysis.	70
	8.1.2 Indirect Discharge Analysis.	70
	8.2 Results of Environmental Assessment	72
	8.2.1 Process Wastewater	72
	8.2.2 Contaminated Cooling Water	73
	8.3 Non-water Quality Environmental Impacts	76
	8.3.1 Air Pollution.	76
	8.3.2 Solid Waste.	76
	8.3.3 Energy Requirements.	76
	8.4 Summary	77
9.	REFERENCES	78

LIST OF TABLES

Table		Page
3-1	EPA Listed Hazardous Wastes From Nonspecific Sources	9
4-1	Estimated Distribution of Commercial Solvent Recyclers by State	17
4-2	Estimated Distribution of Commercial Solvent Recyclers by EPA Region.	18
4-3	Use Distribution of the 10 Most Widely Used Organic Solvents	22
4-4	Copy of Partial Results of the 1982 NASR Survey.	24
4-5	Solvent Volumes Received and Price Ranges Recorded by 8 Firms	25
4-6	Financial Ratios for the Solvent Recycling Industry.	27
5-1	EPA-ITD Sampling Program Comparison of Process Wastewater - Conventionals and Nonconventionals	35
5-2	EPA-ITD Sampling Program Comparison of Process Wastewater - Metals	36
5-3	EPA-ITD Sampling Program Comparison of Process Wastewater - Superscan Metals	37
5-4	EPA-ITD Sampling Program Comparison of Process Wastewater - Extractable and Volatile Organics.	39
5-5	EPA-ITD Sampling Program: Cooling Water and Comingled Nonprocess Wastewater.	42
5-6	Still Bottoms Generated at Plant F	44
5-7	EPA-ITD Sampling Program Still Bottoms - Conventionals and Nonconventionals	45
5-8	EPA-ITD Sampling Program Still Bottoms - Metals.	47
5-9	EPA-ITD Sampling Program Still Bottoms - Extractable and Volatile Organics.	48
5-10	EPA-ITD Sampling Program Still Bottoms - Dioxins/Furans.	49
5-11	EPA-ITD Sampling Program Still Bottoms - TCLP Analysis - Metals.	50
5-12	EPA-ITD Sampling Program Still Bottoms - TCLP Analysis - Extractable and Volatile Organics.	51

LIST OF TABLES (Continued)

Table		Page
6-1	EPA-ITD Sampling Program Steam Stripping Performance - Conventionals and Nonconventionals	55
6-2	EPA-ITD Sampling Program Steam Stripping Performance - Metals	56
6-3	EPA-ITD Sampling Program Steam Stripping Performance - Extractable and Volatile Organics.	57
6-4	BDAT Treatment Standards	59
7-1	Contract Hauling Costs for Process Wastewater.	61
7-2	Economics of a Solvent Recovery Model Plant (800,000 Gallons per Year Capacity)	63
7-3	Economic Impact Measures	65
7-4	Cost-Effectiveness Calculation for Solvent Recyclers (Zero Discharge of Process Wastewater by Contract Hauling)	66
7-5	Cost-Effectiveness Calculation for Solvent Recycling Wastewater Treatment (Cooling Water by Steam Stripping).	69

LIST OF FIGURES

Figure		Page
4-1	General Scheme for Solvent Recycling	19

1. FOREWORD

The Industrial Technology Division (ITD) of the U.S. Environmental Protection Agency (EPA) has conducted a study of the Solvent Recycling Industry as a result of findings from the Domestic Sewage Study that the quantity of hazardous wastes generated and discharged to publicly-owned treatment works (POTWs) by the recycling industry was unknown. The purpose of this ongoing work is to develop information to characterize the solvent recycling industry as to the scope of the industry, its operations, and its discharges to the Nation's waters, and to identify and quantify the pollutants discharged into the Nation's waters.

EPA collected data and information from a variety of sources. The Agency's information-gathering efforts were coordinated with five local governments and all of the states. Pertinent trade associations were contacted and nine sites were visited. Wastewater was sampled at four sites and the data collected represent the best available for characterizing the industry. Analyses were conducted for more than 400 conventional, nonconventional, priority, and Resource Conservation and Recovery Act (RCRA) pollutants.

2. SUMMARY

The following is a summary from the study of the solvent recycling industry conducted by the Industrial Technology Division (ITD) of the U.S. Environmental Protection Agency (EPA).

- The Domestic Sewage Study, conducted by EPA in response to Section 3018(a) of the Resource Conservation and Recovery Act (RCRA), concluded that the quantity of hazardous wastes generated and discharged to publicly-owned treatment works (POTWs) by the solvent recycling industry was unknown.

- Facility inspections and telephone calls conducted by EPA reveal that not all solvent recyclers are RCRA-permitted facilities. Generators of spent solvents are erroneously shipping hazardous wastes to unpermitted facilities in violation of 40 CFR 262.20b.

- Spent solvents are recycled for reuse in fuel blends or as solvents at 210 facilities located throughout the Nation. The U.S. EPA Region with the largest number of recyclers is Region V, with 32 percent of the Nation's facilities. California, Illinois, and Ohio are the states with the largest numbers of recyclers.

- Solvent recyclers are generally registered under SIC Code 2869 - Industrial Organic Chemicals, Not Elsewhere Classified. Spent solvent types include nonhalogenated (75 percent) and halogenated (25 percent).

- Solvent recyclers that recover solvents for reuse are subject to effluent limitations guidelines for the organic chemicals industry (40 CFR 414). Solvent recyclers that recycle solvents for use in fuel blends, only, are not subject to 40 CFR Part 414.

- The average solvent recycler handles 0.8 million gallons of spent solvents annually. Process wastewater discharges average 400 gallons per day, which results primarily from the physical separation of water from spent solvents.

- The status of the industry's process wastewater discharges is as follows:

Discharge Status	Number of Facilities
Direct discharge	10
Indirect discharge	30
Zero discharge	170
TOTAL	210

- The status of the industry's cooling water discharges is estimated as follows:

Discharge Status	Estimated Number of Facilities
Direct discharge	36
Indirect discharge	107
Zero discharge	67
TOTAL	210

- The industry is not expected to grow or decline significantly. Hence, the waste quantities estimated in this report are reasonable projections of future waste quantities.

- Still bottoms are highly concentrated mixtures of solvents, oils, greases, and solids. Nine dioxin and furan compounds were found in still bottoms samples. No discharges of still bottoms to the Nation's waters are known to occur routinely.

- Industry process wastewater is characterized by high concentrations of conventional, nonconventional, metal, and organic pollutants. The data shown below for selected parameters are representative of a typical industry process wastewater:

Parameter	Concentration (mg/l)
BOD_5	76,300
COD	145,000
Oil and Grease	34,400
TOC	111,000
Iron	177
Lead	17
Zinc	92
Acetone	6,590
Methylene Chloride	833
1,1,1-Trichloroethane	82
Trichloroethane	10
Total Toxic Organics	14,000

- Forty-three extractable and volatile organics were detected in industry raw wastewaters. Of these, 40 had industry mean concentrations that exceeded 10 mg/l and 24 had concentrations that exceeded 100 mg/l.

- Zero discharge of process wastewater is achieved by 81 percent of the industry. Contract hauling, fuel blending, and incineration are the primary zero discharge technologies.

- Only half of the discharging facilities treat their wastewater prior to discharge. No single treatment technology prevails among dischargers.

- Zero discharge of process wastewater by contract hauling and incineration is a model treatment system for the treatment of this industry's highly variable wastewaters. A typical facility would incur a capital cost of $20,000 and an annual hauling cost of $260,000.

- Cooling water discharges average 11,000 gallons per day per facility and contain significant levels of pollutants. The data below show concentrations found in this industry.

Parameter	Concentration (mg/l)
BOD_5	919
COD	3,500
TOC	75
Total Toxic Organics	440

- If treatment of cooling water is needed, steam stripping technology is available, which can be transferred to the solvent recycling industry. For treatment of cooling water, the average plant would incur a capital cost of $300,000 and an annual operating cost of $35,000.

- Costs developed in this report are conservative. Solvent recyclers are likely to reduce wastewater volumes prior to shipping wastewater via a contract hauler. Best management practices are probably a more economical alternative than steam stripping for the control of organic pollutants in cooling water. If steam stripping were a selected control technology, new equipment would probably not be purchased. Instead, existing equipment would be retrofit.

- The typical plant treatment costs are calculated at $0.47 per gallon of solvent processed, which represents from 19 to 67 percent of the tolling fees.

- The cost-effectiveness of treating the two types of wastewater is not significantly different, ranging from $79 to $102 per pound equivalent of pollutant removed.

- Total loadings of priority pollutant inorganics from untreated process wastewater are less than the lowest raw waste total inorganics loadings of regulated BAT/PSES industries. Total loadings of priority pollutant organics are more significant and rank in the lower third of the loadings rankings.

- Total loadings of priority pollutant inorganics and organics from untreated cooling and miscellaneous wastewater are low relative to the lowest raw waste loadings from the regulated BAT/PSES industries.

- Implementation of the model cost technologies would result in a significant increase in solid and hazardous waste, and a doubling of energy consumption.

3. INTRODUCTION

The purpose of this section is to present the regulatory authority and pertinent regulations, and to provide an overview of the industry. The sources of data and information used to support the conclusions also are discussed.

3.1 PURPOSE AND AUTHORITY

The Federal Water Pollution Control Act Amendments of 1972 established a comprehensive program to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters, Section 101[a]". Under this statute, existing industrial dischargers were required to achieve compliance with "effluent limitations requiring the application of the best practicable control technology currently available [BPT], Section 301[b][1][A]." These dischargers are required to achieve effluent limitations requiring the application of the best available technology economically achievable [BAT],... which will result in reasonable further progress toward the national goal of eliminating the discharge of all pollutants, Section 301[b][2][A]." New industrial direct discharge performance standards (NSPS), based on best available demonstrated technology, and existing and new dischargers to publicly-owned treatment works (POTWs), are subject to pretreatment standards under Sections 307(b) and (c) of the Act. While the requirements for direct dischargers are to be incorporated into National Pollutant Discharge Elimination System (NPDES) permits issued under Section 402 of the Act, pretreatment standards were made enforceable directly against dischargers to POTWs (indirect dischargers).

Although Section 402(a)(1) of the 1972 Act authorized the setting of requirements for direct dischargers on a case-by-case basis, Congress intended that control requirements be based on regulations promulgated by the Administrator that would provide guidelines that consider the degree of effluent reduction attainable through the application of BPT and BAT. Sections 304(c) and 306 of the Act required promulgation of regulations for NSPS, and Sections 304(f), 307(b), and 307(c) required promulgation of regulations for pretreatment standards. In addition to these regulations for designated industry categories, Section 307(a) of the Act required the Administrator to develop a list of toxic pollutants and promulgate effluent standards applicable to all dischargers of toxic pollutants. Categorical pretreatment standards originally were to be developed for 34 specific industrial categories and 129 pollutants. The U.S. Environmental Protection Agency (EPA) subsequently exempted several industries and pollutants from regulation. Currently, categorical standards apply to 22 specific industrial categories and 126 priority pollutants. Finally, Section 501(a) of the Act authorized the Administrator to prescribe any additional regulations "necessary to carry out his functions" under the Act. The EPA Industrial Technology Division (EPA-ITD) is responsible for developing

effluent guidelines limitations and standards for the categorical industries.

3.2 REGULATORY OVERVIEW

3.2.1 Resource Conservation and Recovery Act

Congress enacted the Resource Conservation and Recovery Act (RCRA) in 1976 to define a Federal role in solid waste resource management and recovery. The Act's primary goals are to: (1) protect human health and the environment from hazardous and other solid wastes, and (2) protect and preserve natural resources through the implementation of programs emphasizing resource conservation and recovery. The principal regulatory focus of RCRA is to control hazardous waste. To this end, RCRA mandates a comprehensive system to identify hazardous wastes and to track and control their movement from generation through transport, treatment, storage, and ultimate disposal. The Act subsequently was amended in 1978, 1980, and 1984.

Hazardous waste management under RCRA has often been characterized as "cradle to grave" management. A firm generating solid wastes is required to determine if such waste is hazardous. Any generator of a hazardous waste must notify EPA. If the generator chooses to move the waste off-site for treatment or disposal, a manifest must be maintained by the generator, transporter, and the receiving treatment, storage, or disposal facility. Any wastes shipped off-site to be treated, stored, or disposed of must be sent to an authorized hazardous waste disposal facility. Wastes managed on-site, like those shipped off-site, must be handled according to specific management and technical requirements in RCRA.

On May 19, 1980, as part of its final and interim regulation implementing Section 3001 of RCRA, EPA published a list of hazardous wastes generated from nonspecific sources. Based on the original listing and subsequent amendments, the list presently includes 31 commonly used organic solvents and mixtures, or blends, which contain, in total, 10 percent or more of the listed solvents. Specifically, included are spent solvents and still bottoms from the recovery of spent solvents. Table 3-1 is a list of the regulated solvents. All persons who handle hazardous waste subject to control under Subtitle C are required to notify EPA according to Section 3010 of RCRA and obtain an EPA ID number.

3.2.2 Domestic Sewage Exclusion

The Domestic Sewage Exclusion (DSE) is specified in Section 1004[27] of RCRA and codified in 40 CFR 261.4[A][1]. Under Section 1004[27] of RCRA, solid or dissolved material in domestic sewage is not, by definition, a "solid waste" and, as a corollary, cannot be considered a "hazardous waste." Thus, the DSE covers:

TABLE 3-1. EPA LISTED HAZARDOUS WASTES FROM NONSPECIFIC SOURCES

EPA Hazardous Waste Number	Hazardous Waste
F001	Tetrachloroethylene
	Trichloroethylene
	Methylene Chloride
	1,1,1-Trichloroethane
	Carbon Tetrachloride
	Chlorinated Fluorocarbons
F002	Tetrachloroethylene
	Methylene Chloride
	Trichloroethylene
	1,1,1-Trichloroethane
	Chlorobenzene
	1,1,2-Trichloro-1,2,2-Trifluoroethane
	Ortho-dichlorobenzene
	Trichlorfluoromethane
F003	Xylene
	Acetone
	Ethyl Acetate
	Ethyl Benzene
	Ethyl Ether
	Methyl Isobutyl Ketone
	N-Butyl Alcohol
	Cyclohexanone
	Methanol
F004	Cresols
	Cresylic Acid
	Nitrobenzene
F005	Toluene
	Methyl Ethyl Ketone
	Carbon Disulfide
	Isobutanol
	Pyridine

- "Untreated sanitary wastes that pass through a sewer system"

- "Any mixture of domestic sewage and other wastes that passes through a sewer system to a POTW for treatment."

The premise behind the exclusion is that it is unnecessary to subject hazardous wastes mixed with domestic sewage to RCRA management requirements, since these DSE wastes receive the benefit of treatment offered by POTWs and are already regulated under Clean Water Act (CWA) programs, such as the National Pretreatment Program and the National Pollutant Discharge Elimination System (NPDES).

The exclusion allows industries connected to POTWs to discharge hazardous wastes to sewers containing domestic sewage without having to comply with certain RCRA generator requirements, such as manifesting and reporting requirements. Moreover, POTWs receiving excluded wastes are not deemed to have received hazardous wastes and, therefore, are not subject to RCRA treatment, storage, and disposal facility requirements.

EPA conducted a study in response to Section 3018(a) of the Resource Conservation and Recovery Act (USEPA 1986c). This provision required that EPA prepare

> "a report to the Congress concerning those substances identified or listed under Section 3001 which are not regulated under this subtitle by reason of the exclusion for mixtures of domestic sewage and other wastes that pass through a sewer system to a publicly-owned treatment works. Such report shall include the types, size and number of generators which dispose of such substances in this manner, the types and quantities disposed of in this manner and the identification of significant generators, wastes, and waste constituents not regulated under existing Federal law or regulated in a manner sufficient to protect human health and the environment."

The report is known as the Domestic Sewage Study and is an evaluation of the impacts of wastes discharged to local wastewater treatment plants.

In performing this study, EPA collected information on waste discharges from 47 industrial categories and the residential sector. Results of the evaluation concluded that the quantity of hazardous wastes generated and discharged to POTWs by the solvent recycling industry was unknown. EPA's regulatory efforts, in the past, have focused on larger industrial categories. The solvent recycling industry traditionally has been considered a less significant waste source because of its small size and service-related orientation. Therefore, this industry has never been extensively reviewed at the national level for possible regulation under the CWA.

3.2.3 Land Disposal Restrictions

On November 7, 1986, EPA promulgated regulations that restrict the land disposal of the solvents listed under EPA Hazardous Waste Nos. F001, F002, F003, F004, and F005 (40 CFR 268). These wastes are prohibited from land disposal unless deepwell injected, generated by a small quantity generator, generated by an action under RCRA or the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), or contained in a mixture with less than 1 percent total solvents. The Agency has determined that land disposal restrictions will result in increased demand for commercial distillation capacity. The Agency also has estimated that existing distillation capacity should be sufficient to accommodate any resulting shifts in solvent management practices.

3.2.4 Accumulation Time Exemption

A generator who treats, stores, or disposes of hazardous wastes on-site must apply for a facility permit and comply with the conditions in 40 CFR Parts 264 and 265. Regulations for owners and operators of permitted hazardous waste facilities are addressed by Part 264. However, a generator may accumulate hazardous waste on-site for 90 days or less, without a permit or without having interim status (40 CFR 262.34). As generators of still bottoms and highly concentrated wastewater, solvent recyclers may exercise the accumulation time exemption.

Spent solvents are also hazardous wastes, but these wastes are generated at the sources and not at the solvent recycling facilities. The generators of the spent solvents are required to designate, on the manifest, one facility that is permitted to handle the waste described on the manifest (40 CFR 262.20b). Hence, solvent recyclers that receive spent solvents should be RCRA-permitted facilities. Facility inspections and telephone calls conducted by the Agency reveal that not all solvent recyclers are RCRA-permitted facilities. Many recyclers believe that the accumulation time exemption applies to their facility. On the other hand, generators of spent solvent who are erroneously shipping hazardous wastes to unpermitted facilities are in violation of 40 CFR 262.20b.

3.3 OVERVIEW OF THE INDUSTRY

The Agency has identified 210 facilities that recycle solvents on a commercial basis. The average facility employs eight employees (NASR 1982). Solvent recycling became popular in the 1970's; hence, few facilities are believed to be more than 20 years old.

Data on effluent discharges from solvent recyclers are limited, since most dischargers are regulated by local pretreatment authorities that do not require extensive monitoring. The Agency estimates that process wastewater is discharged from approximately

40 facilities based on telephone data-gathering efforts (SAIC 1987a). Furthermore, only 10 of these 40 facilities are estimated to be direct dischargers based on a review of the Agency's Industrial Facilities Database (SAIC 1986a). In addition to process wastewater, solvent recyclers also discharge cooling water. About 68 percent of the 210 identified facilities are estimated to be dischargers of cooling water (SAIC 1987b). Based on the ratio of direct and indirect process wastewater dischargers (10:30), the numbers of direct and indirect dischargers of cooling water are 36 and 107, respectively.

The solvent recycling industry is not included in a specific U.S. Department of Commerce, Bureau of Census Standard Industrial Classification (SIC). Many solvent recyclers have identified themselves under SIC Code 2869 - Industrial Organic Chemicals, Not Elsewhere Classified. Most facilities classified under SIC 2869 are subject to effluent guidelines and standards for the Organic Chemicals, Plastics, and Synthetic Fibers (OCPSF) Point Source Category. Subpart G - Bulk Organic Chemicals, includes process wastewater discharges resulting from the manufacture of many of the solvents recycled in the solvent recycling industry (40 CFR 414). However, some solvent recyclers only recycle solvents for use in fuel blends and are not subject to OCPSF regulations. Furthermore, noncontact cooling water discharges are not covered under OCPSF effluent guidelines.

3.4 DATA AND INFORMATION GATHERING

The Agency sought to obtain a broad and accurate understanding of the solvent recycling industry and to evaluate wastewater characteristics and treatment practices. This involved a review of the literature, meetings with Federal and local agencies, facility site visits, and identification of all facilities potentially in the solvent recycling universe. In summary, the major sources of data and information are as follows:

- State and local agencies
- Trade associations
- Telephone contacts
- Literature review
- Facility site visits.

3.4.1 State and Local Data

The Agency contacted all state hazardous waste offices by telephone and mail to identify names of solvent reclaimers. In some cases, no information was available, since some states do not regulate solvent reclaimers as hazardous waste facilities if hazardous wastes are stored on-site for less than 90 days. In other cases, the state's facility data base does not indicate the nature of a facility's activity. In addition, hazardous waste offices in 18 states do not track solvent reclaimers. Attempts were made to contact territories of the United States; however, information was

not readily available. Permit applications, industrial user permits, and monitoring data were obtained from the following agencies:

- The Metropolitan Sanitary District of Greater Chicago
- The City of Detroit Water and Sewage Department
- The County Sanitation District of Los Angeles County
- The City of San Antonio Department of Wastewater Management
- The State of Washington, Department of Ecology.

3.4.2 Trade Associations

Membership directories and address lists were requested, by mail, from 12 associations that are active in the waste management field. Lists were received from the following five associations:

- Association of Petroleum Re-refiners
- Chemical Waste Transportation Council
- Institute of Chemical Waste Management
- National Association of Solvent Recyclers
- Spill Control Association of America.

Five additional trade associations also were contacted by telephone. However, based on conversations with association directors, these are not believed to be pertinent to this study.

In March 1982, the National Association of Solvent Recyclers (NASR) released the results of its member survey. Twenty-five responses were received out of 38 questionnaires sent out. The survey asked 13 questions relating to plant production. Survey results are included in Appendix A of this report.

3.4.3 Telephone Contacts

The Agency contacted 204 potential solvent recycles for the purpose of verifying information contained in the Agency's Industrial Facilities Database and the Hazardous Waste Data Management System. Solvent recyclers were asked whether commercial recovery was conducted on-site and whether process wastewater was discharged to a POTW or to surface water. Of the 204 facilities targeted to contact, 97 could not be contacted, no longer recover solvents, or act only as transfer stations. Out of the remaining 107 facilities, only 21 reported direct/indirect discharge of the solvent recovery process wastewater.

3.4.4 Literature Review

The Agency undertook a literature search of information on this industry. Numerous articles report data on in-plant solvent recovery at paint, ink, metal finishing, chemical, rubber, plastics, and other manufacturing industries. However,

comparatively few articles are available on the commercial solvent recovery industry. The primary literature sources are "Source Assessment: Reclaiming of Waste, Solvents, State of the Art," published by EPA's Office of Research and Development (EPA-ORD) in April 1978, and "Best Demonstrated Available Technology (BDAT) Background Document for F001-F005 Spent Solvents," published by EPA's Office of Solid Waste (EPA-OSW) in November 1986.

3.4.5 Facility Site Visits

The Agency contacted numerous solvent recyclers to identify candidates for wastewater sampling. Site visits were conducted to locate sample points in the facilities and to collect file information. Facilities that did not treat wastewater or did not have accessible sample points were not selected for sampling. Presampling and sampling site inspections were conducted at the following ten facilities:

- Clayton Chemical Company, Sauget, Illinois
- Chemical Processors Incorporated, Seattle, Washington
- Environmental Processing Services, Dayton, Ohio
- KDM Company, San Antonio, Texas
- Oil and Solvent Process Company, Azusa, California
- Omega Chemical Corporation, Whittier, California
- Organic Chemicals Incorporated, Grandville, Michigan
- Prillaman Chemical Corporation, Martinsville, Virginia
- Romic Chemical Corporation, East Palo Alto, California
- Spectron Incorporated, Elkton, Maryland.

In summary, the Agency coordinated its information-gathering efforts with five local governments and the states. Pertinent trade associations were contacted and a literature search was conducted. Ten facilities were visited and 204 were targeted to be contacted by telephone. The Agency believes that the conclusions presented in this report reflect the best information available.

4. DESCRIPTION OF THE INDUSTRY

The purpose of this section is to discuss industry products and processes, as well as facility characteristics. This information is necessary to establish groupings within the industry. These grouping should reflect differences in wastewater generation, control, treatment, and discharges.

4.1 INDUSTRY PROFILE

Commercial solvent recycling is defined in this report as the recycling of spent solvents that are not the byproduct or waste product of a manufacturing process or cleaning operation located on the same site. Any recovery operation is considered commercially available if it is offered to other parties not under the same ownership as the recovery operation. A commercial recovery plant may be operated on a site where unrelated products are manufactured. This study does not cover recovery operations that are an integral part of a main process, such as solvent refining, or vegetable oil manufacturing. This study does not cover recovery operations that are added onto a process. For example, some surface coating and cleaning industries add on recovery operations to reclaim spent solvents that are reused on-site.

Solvent recycling became popular in the 1970's as a means of reusing the solvents. During this time, the cost of solvents increased many times following increases in the cost of crude oil. The cost of recovering solvents, primarily through distillation, became increasingly economical. Additionally, air and water pollution legislation, along with the Resource Conservation and Recovery Act (RCRA), which classified spent solvents as hazardous wastes, resulted in a restructuring of ways to dispose of solvents and in increasing disposal costs. As a result of these occurrences, many industries have installed solvent reclaiming facilities on their plant sites. However, the majority of companies in other manufacturing industries that generate spent solvents have opted to ship them to off-site commercial recyclers rather than installing on-site recycling facilities. These recyclers accept various types of solvents from various manufacturing industries, and either return the solvent to the industry that sent it, or sell the solvent to companies in other industries.

Spent solvents are recycled in a variety of ways for the purpose of reusing the product as a solvent or in fuel blends. The products recycled for use as solvents are refined in specially constructed distillation columns, where the solvent separates as a condensate from the resins and pigments that remain as still bottoms. The condensate is collected, tested for conformance with commercial specifications, and sold for use as a primary product. Spent solvents and still bottoms recycled for reuse as fuel typically are collected and blended to meet predetermined fuel

specifications and are used as a fossil fuel substitute in cement kilns or as a feedstock for blast furnaces. The process can range in complexity from this simple operation to a complex multistep distillation.

In 1981, 173 million gallons of spent solvents were shipped off-site by generators to commercial recyclers (Engineering Science 1985). Therefore, each of the 210 estimated commercial recyclers receives an average of 0.82 million gallons annually. This estimate does not compare well with an NASR (1982) estimate of 1.99 million gallons for an average facility. Reasons for the difference are probably due to the small sample size in the NASR survey. Only 18 facilities provided information on throughput, and these facilities reported annual recycling rates ranging from 0.12 to 8.4 million gallons. Since the estimate of 173 million gallons was determined by an independent source, a typical facility throughput of 0.8 million gallons is reasonable.

Solvent reclaimers have three general markets (NASR 1986):

- Batch Toll Processing. Some customers have long-term contracts with a recycler to handle their particular spent solvents, separate reusable solvent from contaminants, and return the recycled solvents. The fee depends on difficulty of separation and market supply and demand conditions.

- Open Market. Recycling also may be considered a manufacturing process that uses spent solvents as raw materials. The spent solvents are recycled to specification and the product is sold on the open market.

- Industrial Furnace Fuel. Spent solvents and solvent still bottoms receive some physical treatment and are blended with fuel for use in industrial furnaces and cement kilns.

The Agency estimates that there are 210 off-site commercial recyclers. This estimate is based on 312 facility names reported in literature and identified by state and local contacts, and trade associations. The Agency contacted, by telephone, 204 of these facilities to verify their status. Of the 157 responses received, 51 indicated that they had ceased operations or no longer handled spent solvents. Consequently, the universe of solvent recyclers is estimated to be 210 facilities, where $(157-51)/157 \times 312 = 210$.

Table 4-1 lists the potential solvent recyclers classified by state. The states with the largest number of potential recyclers are California, Illinois, Ohio, and Michigan. Table 4-2 lists the potential solvent recyclers sorted by U.S. Environmental Protection Agency (EPA) Region. Of the 210 estimated facilities, 30 percent are located in EPA Region V. The list of 312 facility addresses is included in Appendix B (Boubel 1985; Environmental Information Ltd. 1986; EPA 1985a).

TABLE 4-1. ESTIMATED DISTRIBUTION OF COMMERCIAL SOLVENT RECYCLERS BY STATE

State	Estimated Number of Plants
Alabama	1
Arizona	5
Arkansas	3
California	22
Colorado	4
Connecticut	1
Delaware	1
Florida	3
Georgia	5
Hawaii	1
Idaho	1
Illinois	17
Indiana	8
Iowa	1
Kansas	1
Kentucky	4
Louisiana	1
Maine	1
Maryland	1
Massachusetts	7
Michigan	13
Minnesota	8
Mississippi	1
Missouri	7
Nebraska	5
New Jersey	5
New Mexico	1
New York	10
North Carolina	1
North Dakota	1
Ohio	16
Oklahoma	3
Oregon	3
Pennsylvania	8
Rhode Island	1
South Carolina	7
Tennessee	4
Texas	9
Utah	1
Virginia	1
Washington	11
Wisconsin	5
(Puerto Rico)	1
Total	210

TABLE 4-2. ESTIMATED DISTRIBUTION OF COMMERCIAL SOLVENT RECYCLERS BY EPA REGION

EPA Region	Estimated Number of Plants
I	11
II	16
III	11
IV	26
V	67
VI	17
VII	14
VIII	6
IX	27
X	15
Total	210

4.2 SOLVENT RECYCLING PROCESSES

The solvent recovery process involves the unit operations, which include storage and handling, initial treatment, distillation, and purification. These unit operations are shown in Figure 4-1. Most commercial solvent recovery operations are included under this process description. Methods employed in each unit operation are described in this section (Scofield 1975; Tierney 1978; EPA 1986a).

4.2.1 Solvent Storage Handling

Solvents are stored before and after recovery. For example, private contractors reclaim solvents from a variety of industries, such as paint manufacturers and degreasing operations. The solvents are transported from the industrial site, in tank cars and drums, to the reclaiming plant, where they are recovered and then returned to the site or sold to another plant for reuse.

Solvents are stored in containers ranging in size from 55-gallon drums to tanks with capacities of 20,000 gallons or more. Drummed solvents are segregated by solvent type. Storage tanks are of fixed or floating roof design. Fixed-roof tanks are metal cylinders or boxes of rigid construction. Venting systems are used to prevent solvent vapors from creating excessive pressure inside the tanks. Floating-roof tanks have movable tops that float on the surface of the contained solvent and form air-tight seals with the tank walls.

4.2.2 Initial Treatment

Received spent solvents are initially treated by mechanical separation to remove suspended solids and water. Methods for mechanical separation include decanting, filtering, draining, settling, and centrifugation. Decanting also is used to separate water from immiscible solvent.

4.2.3 Distillation

After initial treatment, waste solvents destined for reuse as solvents are distilled to separate solvent mixtures and to remove dissolved impurities. Spent solvents intended to be reused in fuel blends are not distilled. Waste solvents are distilled by one of the five methods listed below:

- Simple batch distillation
- Simple continuous distillation
- Steam distillation
- Batch rectification (fractional distillation)
- Continuous rectification (fractional distillation).

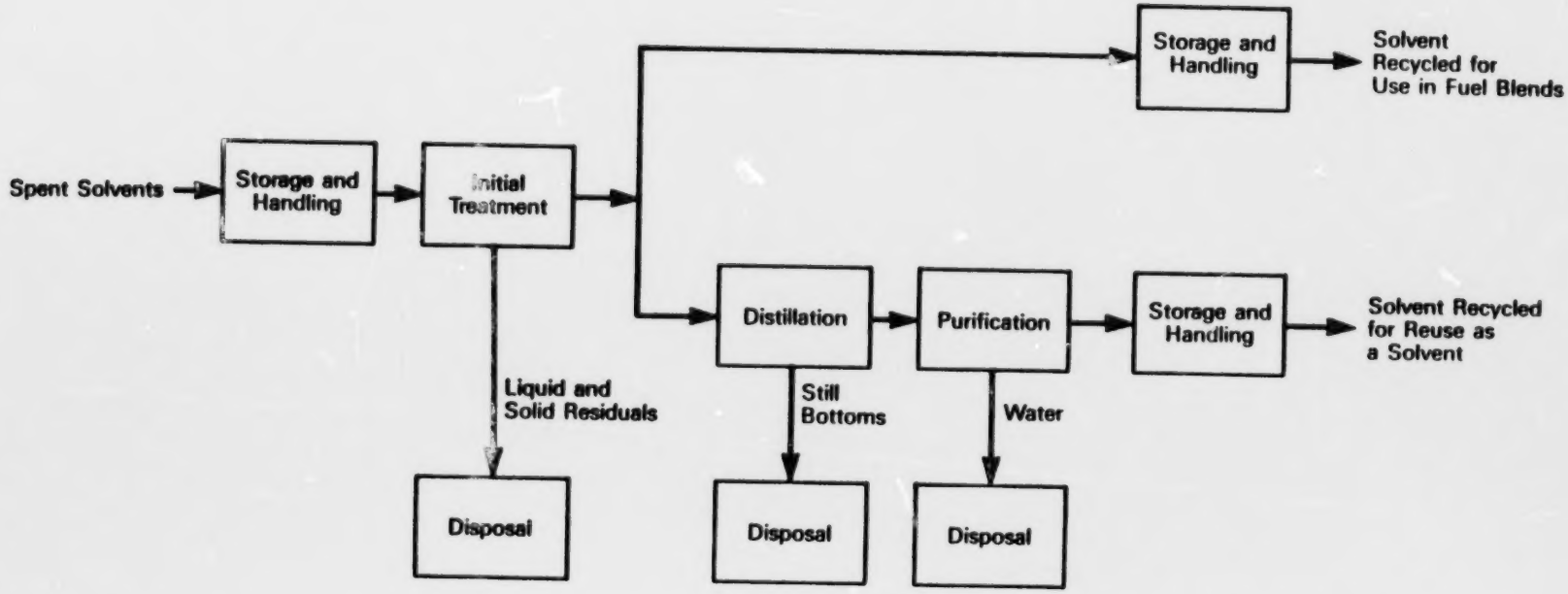

Figure 4-1. General Scheme for Solvent Recycling

In simple batch distillation, a quantity of waste solvent is charged to the evaporator. After charging, vapors are continuously removed and condensed. The resulting still bottoms are removed from the evaporator after solvent evaporation. Simple continuous distillation is the same as batch distillation except that solvent is continuously fed to the evaporator during distillation, and still bottoms are continuously drawn off. Both batch and continuous distillation equipment include the use of coils to transfer heat required for evaporation. In steam distillation, solvents are vaporized by direct contact with steam that is injected into the evaporator. Batch, continuous, and steam distillations are suitable for separating solvents from their dissolved contaminants.

The separation of mixed solvents usually requires multiple simple distillations or rectifications. In batch rectification, solvent vapors pass through a fractionating column where they contact condensed solvent (reflux) entering at the top of the column. Solvent not returned as reflux is drawn off as overhead product. In continuous rectification, the waste solvent feed enters continuously at an intermediate point in the column. The more volatile solvents are drawn off at the top of the column while higher boiling point solvents are collected at the bottom.

Common distillation and rectification equipment is not appropriate for the recovery of some spent solvents. For example, resinous or viscous contaminants can coat heat transfer surfaces, resulting in a loss of evaporator efficiency. Evaporators with heating coils exposed to waste solvent are only suitable for solvents with less than 5 percent solids content. Two evaporators that prevent contaminants from fouling heating surfaces are of the scraped surface or thin-film design. In the scraped-surface type, rotating scrapers keep contaminants from adhering to the heated evaporator walls. For heat sensitive or viscous materials, thin-film evaporators are the most suitable. With this design, solvent is forced into a thin film along the heated evaporator walls by rotating blades. These blades agitate the solvent while maintaining a small clearance from the evaporator walls to prevent contaminant buildup on heating surfaces.

Azeotropic solvent mixtures, which are normally difficult to separate, can be separated during distillation by adding a third solvent component. For example, the addition of phenol to cyclohexane-benzene mixtures during distillation causes the activity coefficients for cyclohexane to be nearly twice as large as those for benzene. This factor causes the volatility of cyclohexane to be nearly twice that of benzene, allowing for easy separation by distillation.

Condensation of solvent vapors during distillation is accomplished by shell and tube or barometric condensers. The shell and tube design consists of parallel tubes running through a cylindrical shell. Condensation of solvent is accomplished by the flow of cooling water through the tubes, which are in contact with solvent vapors in the shell. This arrangement prevents the mixing

of reclaimed solvent and cooling water. In barometric condensers, vapor is condensed by direct contact with a spray of cooling water. Condensation of vapor results in a mixture of solvent and cooling water.

Solvents with high boiling points (155°C) are most effectively distilled under vacuum. Vacuum distillation greatly reduces the amount of heat that would otherwise be required by atmospheric distillation.

4.2.4 Purification

After distillation, additional water is removed from solvent by decanting or salting. Additional cooling of the solvent-water mix before decanting increases the separation of the two components by reducing their solubility. In salting, solvent is passed through a calcium chloride bed where water is removed by absorption.

During purification, some reclaimed solvents may lose buffering capacity and require stabilization. Stabilization requires the addition of buffers to ensure that pH is kept constant during use. The composition of buffering additives is considered proprietary by most companies.

4.3 SOLVENT USAGE AND SPENT SOLVENT GENERATION

The types of solvents in use by industry are indicative of the types of solvents recovered at commercial facilities. Spent solvents are the result of product synthesis, solubilizing of active ingredients, surface cleaning, and equipment cleaning. In processes that involve reactions, solvents are sometimes used to dissolve reactants or products to keep the reaction single-phased or to aid in the purification or drying of products. Spent solvent wastes can be generated in subsequent product purification or solvent recovery steps. In the paint, ink, and dye industries, for example, solvents are used to dissolve active ingredients and to aid in the application of the product. Solvent waste is usually generated during both the production and application of surface coatings. Surface cleaning includes both industrial degreasing of metal products and repair work. Surface cleaning is practiced as either cold degreasing, in which solvent is held below its boiling point, or as vapor degreasing, in which solvent vapors are condensed on the product surface. Solvents are used in virtually every industry for equipment and process cleaning.

The use distribution of the 10 most widely used organic solvents with respect to 5 major industry groups is shown in Table 4-3 (Pope-Reid 1986). The paint and allied products group primarily uses nonhalogenated solvents, while the surface cleaning group primarily uses halogenated solvents. Tetrachloroethylene is the main solvent used by laundries and dry cleaners.

TABLE 4-3. USE DISTRIBUTION OF THE 10 MOST WIDELY USED ORGANIC SOLVENTS (million lbs per year)

	Xylene	Methanol	Toluene	Tetrachloro-ethylene	Methylene Chloride	Methyl Ethyl Ketone	Trichloro-ethylene	1,1,1-Trichloro-ethane	Acetone	Methyl Isobutyl Ketone	Total
Paint and Allied Products	539	660	642	-	25	363	-	16	200	134	2579
Surface Cleaning incl. Electronics	-	-	-	131	96	-	177	460	N/A	-	864
Pesticides	539	-	-	-	25	-	-	10	-	18	592
Pharmaceu-ticals	N/A	2	55	-	38	N/A	-	N/A	N/A	18	113
Laundry and Dry Cleaning	-	-	-	458	-	-	15	-	-	-	473
Total	1078	662	697	589	184	363	192	486	200	170	

N/A: Solvent at issue probably is used, but the amount is not known (Pope-Reid 1986).

NASR (1982) collected information from 25 of its members on the kinds of solvents each recovers, the types of processes used, and the types of industries served. Table 4-4 is a copy of the NASR survey results. Nonhalogenated and petroleum solvents constitute 73 percent of the spent solvents processed. The remainder is composed of halogenated compounds -- 26 percent, and "others" -- 1 percent. The recovery processes employed typically reclaim 74 percent of the spent solvents for reuse. A wide range of industries is served and spent solvent storage time averages 17 days. Two-thirds of the facilities employ distillation. About 80 percent of recycled solvents are returned to the generator and the remaining 20 percent are sold on the open market.

The cost recycling spent solvent is affected by many factors. In some instances, a spent solvent with a high heat content is sold for reuse in fuel blends. Thus a spent solvent generator is paid, or credited, for the spent solvents. The cost also depends upon the origin of the spent solvent. For example, halogenated solvents used in degreasing cost almost three times as much to recycle as do halogenated solvents which were used for electronic components cleaning. Table 4-5 shows ranges of costs for recycling spent solvents for the years 1981 through 1985. The ranges of costs and volumes received are based on data collected by EPA for eight solvent recyclers (USEPA 1986d). Historically, prices of recycled solvents remained stable until 1983, when they rose sharply. The price ranges in the 1984-1985 period then leveled off to a cost of $3.0 per gallon for solvents recycled for reuse as solvents. Spent solvents sold for use in fuel blends netted a credit of $0.25 per gallon.

4.4 INDUSTRY SUBCATEGORIZATION

The primary purpose of industry subcategorization is to establish groupings within the solvent recycling industry such that each has a uniform set of effluent limitations. This requires that the elements of each group be capable of using similar treatment technologies to achieve effluent limitations. Thus, the same wastewater treatment and control technology is applicable within a subcategory and a uniform treated effluent results from the application of a specific treatment and control technology.

Sufficient information on the aspects listed above is not presently available for the purpose of subcategorizing the solvent recycling industry. However, product type and manufacturing process are potential bases for future subcategorization. Product types could be delineated as halogenated or nonhalogenated solvents, since the level of halogenated compounds in wastestreams could affect ultimate disposal. For example, high halogen content inputs to incinerators are not desirable. The manufacturing process aspect could be characterized by the use or lack of use of distillation equipment. Solvents reclaimed for reuse in fuel blends would only use initial treatment. Solvents distilled for reuse as solvents could require the use of steam in flash

TABLE 4-4. COPY OF PARTIAL RESULTS OF THE 1982 NASR SURVEY

Question 13. What are the main kinds of solvent you recycle, what is the recycling process(es), and what is the type of industry that uses the solvent(s)?

PLEASE FILL IN THE CHART:

	Solvent	Amount	Recycling Process	Percent of Recovery	Storage Time	Type of Industry
Nonhalogenated	Ketones, glycerine, esters, paint and ink, glycol ethers, lacquer thinner, alcohols, acetone, MEK, IPA	43%	Wipe film, vacuum distillation, fractional distillation, flash distillation, thin film evaporator, pot stills	74%	17 days average	Chemical, paint and ink, medical equipment, fiberglass, electronics, coatings, adhesives, and pharmaceutical
Petroleum	Metal, paint, petroleum, coatings, electronics, mineral spirits, xylene, toluene, napthas, aliphatics, aromatics, hexane, stoddard	30%	Flash distillation, fractional distillation, thin-film processor, vacuum distillation, pot stills, fractionation electronics	73%	15 days	Metals, paints, machine shops, average automotive, rubber and sealant resin manufacturing, textiles, plastics, building materials, coatings, petroleum, and
Halogenated	Azeotropes, methylene, chloride, adhesives, plastics, freon, trichloroethylene, 1,1,1-trichloroethane, methylene chloride, perchloroethane, chlorinated, fluorinated, TCE, PCE, CFC-113	26%	Thin-film processors, fractional distillation, pot stills, fractionation, vacuum distillation, flash evaporators	74%	19 days	Degreaser, plastics, strip-average pers, electronics, metals, resin manufacturing, automotive, machine shop, fiberglass, printing aerospace, coatings, printed circuits, and pharmaceutical
Other	Thinner, mill wash, triflourotrichloroethane, mineral oil, freon, methanol, nonhalogenated, MIBK, ink wash solvent, lithium bromide	1%	Evaporation, distillation	20% to 95%	1 to 60 days	

Note: On above chart the percentage of recovery ranged from 20 to 95 percent and the time in storage from 1 to 90 days.

TABLE 4-5. SOLVENT VOLUMES RECEIVED AND PRICE RANGES RECORDED BY 8 FIRMS

Year	Volumes Received (million gallons)	Price Range ($/gallon)
1980	24.3	0.19-0.80
1981	N/A	0.25-1.00
1982	39.0	0.25-1.00
1983	63.9	0.14-1.30
1984	17.6	(0.06)-3.00*
1985	33.1	(0.25)-3.00*

* Figures in parentheses refer to a credit.

Source: USEPA, 1986d

distillation, or the use of fractional distillation, in addition to initial treatment. At this time, however, data are insufficient to support these potential subcategories.

4.5 POTENTIAL FOR INDUSTRY GROWTH

No significant growth is projected for this industry based on findings by the National Association of Solvent Recyclers (NASR) and EPA. In 1982, 19 of 25 NASR survey respondees anticipated facility expansions through 1985. Additional facilities were planned for Colorado, Florida, Massachusetts, Oklahoma, Texas, and Utah. Since that time, prices for petroleum solvents products have generally fallen and production levels for many solvents have not risen. In 1986, plant personnel at a site visited by the Agency stated that business was off because of the depressed economic conditions in oil-producing states.

In 1986, the Agency promulgated regulations to control land disposal of solvent wastes (EPA 1986b). An analysis was conducted to demonstrate the effect of the regulation on the commercial solvent recyclers and other industries that recover solvents. The analysis showed that the regulation would not create the need for additional plant capacity.

4.6 FINANCIAL CHARACTERISTICS OF COMMERCIAL FACILITIES

EPA collected financial data for a group of companies that operate commercial hazardous waste treatment and disposal facilities. A subgroup of firms that operate solvent recycling facilities were identified. The subgroup consists of firms owning a total of 114 facilities, of which: 17 are owned by publicly-held firms, 90 by privately-held firms, 4 by bankrupt firms, and 3 have discontinued operations. This section presents data on the public and private firms. Many of the firms operating commercial solvent recycling facilities are involved in other activities and so their net income, cash flow, and total assets may not be representative of solvent recovery, per se. Nevertheless, this is the best data available at this time.

Privately-held firms are more prevalent than publicly-held firms as shown in Table 4-6. For the two groups of firms two financial ratios are presented; net income compared to total assets, and cash flow compared to total assets. Cash flow includes depreciation (a non-cash, accounting expense), and so is greater than net income. In terms of the average ratio of net income to total assets, the values are 8 percent and 7 percent for public and private firms, respectively. However, the estimate has a wide dispersion; hence the two values do not differ statistically to a significant level. In terms of the second ratio, cash flow to total assets, the values are 15 percent and 13 percent for public and private firms, respectively. These two values also are not statistically different. Overall, public firms do not perform differently from private firms as measured by these two financial ratios.

TABLE 4-6. FINANCIAL RATIOS FOR THE SOLVENT RECYCLING INDUSTRY

Net Income to Total Assets for Firms Owning Commercial Facilities

	Number of Firms	Minimum Ratio (%)	Maximum Ratio (%)	Average Ratio (%)	Standard Deviation
Public Firms	6	2.0	15.0	8.0	5.0
Private Firms	78	-6.0	38.0	7.0	5.3

Cash Flow to Total Assets for Firms Owning Commercial Facilities

	Number of Firms	Minimum Ratio (%)	Maximum Ratio (%)	Average Ratio (%)	Standard Deviation
Public Firms	6	6.0	22.0	15.0	5.0
Private Firms	65	4.0	41.0	13.0	9.7

4.7 SUMMARY

The following list summarizes the major points discussed in this section:

- Spent solvents are recycled for reuse in fuel blends or as solvents at approximately 210 facilities located throughout the Nation. The U.S. EPA Region with the largest number of reconditioners is Region V, with 32 percent of the Nation's facilities. California, Illinois, and Ohio are the states with the largest numbers of reconditioners.

- Solvent recyclers are generally registered under SIC code 2869 - Industrial Organic Chemicals, Not Elsewhere Classified. Spent solvent types include nonhalogenated (75 percent) and halogenated (25 percent).

- The average solvent recycler handles 0.8 million gallons of spent solvents annually. Process wastewater discharges average 400 gallons per day and result primarily from the physical separation of water from spent solvents.

- The status of the industry's process wastewater discharges is estimated as follows:

Discharge Status	Estimated Number of Facilities
Direct discharge	10
Indirect discharge	30
Zero discharge	170
TOTAL	210

- The status of the industry's cooling water discharges is estimated as follows:

Discharge Status	Estimated Number of Facilities
Direct discharge	36
Indirect discharge	107
Zero discharge	67
TOTAL	210

- The industry is not expected to grow or decline significantly. Hence, the waste quantities estimated in this report are reasonable projections of future waste quantities.

5. WATER USES AND WASTEWATER CHARACTERIZATION

The purpose of the section is to describe sources, volumes, and characteristics of wastewaters generated by solvent recovery processes. This chapter also presents a discussion of analytical methodology and factors affecting the recovery of pollutants and their quantification.

5.1 POLLUTANT ANALYSIS, RECOVERY, AND QUANTIFICATION

In order to interpret analytical data fully, quality assurance/quality control (QA/QC) information must first be evaluated. This is especially true for the analysis of organic pollutants. Of particular concern in organics analysis is percent recovery. For example, if 100 µg/l of a compound is reported but the percent recovery is 50 percent, the real concentration could be 200 µg/l. Conversely, if the recovery is 1,000 percent, the real concentration could be 10 µg/l. Expected recoveries for organic compounds using Contract Laboratory Protocols (CLP) are 60 to 150 percent, and for pesticides the recovery is 60 to 200 percent. The percent recovery for a compound becomes increasingly important when concentrations are low (i.e., near their detection limits).

The detection limits for the various organics in the U.S. Environmental Protection Agency, Industrial Technology Division (EPA-ITD) industry sampling effort ranged from 10 to 5,000 µg/l, depending on the compound and the sample. Several reasons for this wide range include:

- A sample extract containing a large concentration of organics can overload the GC/MS. Consequently, the full-strength extract cannot be analyzed, making dilutions necessary and resulting in high detection limits.

- Some detection limits are high, even in "clean water." For example, the detection limit for organics in reagent water ranges from 10 µg/l to 250 µg/l.

- High concentrations of a few compounds can overshadow other results. In this case, it may be necessary to use large dilutions to quantify the compounds present in high concentrations, thereby diluting those found in low concentrations. When the full-strength extract is rerun to detect and quantify the low concentration compounds, the high concentration compounds mask their presence.

- Some polar compounds (such as organic acids) are readily soluble in water, and are hard to separate and analyze

with a GC. Furthermore, some polar compounds do not extract well during the extraction procedure.

Variability inherent in the methods used to analyze conventional and nonconventional pollutants also must be evaluated in order to interpret analytical data. For example, EPA-ITD analytical results for BOD_5 are only accurate to $\pm$ 30 percent within a 95 percent degree of confidence. Consequently, dissolved BOD_5, a fraction of total BOD_5, can be reported within method accuracy limits, to be 60 percent greater than total BOD. A similar circumstance exists for ammonia, which is a fraction of total Kjeldahl nitrogen. The levels of precision and accuracy reported by EPA-ITD are for analyses conducted on natural water samples, not the complex matrices found in samples collected during this study. Furthermore, precision and accuracy data are not available for parameters such as COD and solids.

Such analytical problems were experienced by the laboratories used during the 1986-87 sampling programs. This resulted in pollutants not being found in samples, when high concentrations of these pollutants had been found in similar wastewaters in other samples. Future ITD sampling analysis efforts will be designed to correct these problems.

5.2 WATER USAGE

Since separation of water from spent solvents is a goal of solvent recovery, little water is used in any processing step. Flash distillation is the only process that requires the use of water in a contact mode. In this process, steam is injected into a distillation unit.

The National Association of Solvent Recyclers (NASR) (1982) reports the use of vacuum stills that may be sources of process wastewater. However, information on vacuum distillation was not available to the Agency during its visits to 10 facilities and only one NASR survey respondent reported its use.

Cooling is the only other significant process use of water. Cooling water is used to cool pumps and to condense solvent vapors through the use of condensers. The volume of cooling water used varies greatly from plant to plant.

5.3 WASTEWATER SOURCES

Wastewater generated by solvent recovery processes is the result of initial treatment, distillation, and purification processes. The Agency estimates that the volume of process wastewater generated by these collective processes can range from less than 1 percent to as much as 15 percent of the total volume

of spent solvents. The individual process wastestreams total only several hundred gallons daily at any facility. Therefore, process wastestreams are seldom segregated for individual treatment. However, noncontact cooling water is generally segregated from process wastewater. The discussions below on process wastewater and cooling water demonstrate that each contains significant levels of contaminants.

5.3.1 Process Wastewater

Solvent recovery process wastewater is composed of water that has been separated from spent solvents, distilled solvents, and still bottoms. Cone bottomed tanks, which provide gravity separation, and fractional distillation units are the main sources of wastewater.

Cone bottomed tanks, where gravity separation occurs, are commonly used to store received spent solvents and still bottoms. Since water is denser than most organic solvents, it is drained off the bottom of the tanks, along with solids. Salts that are soluble in water, but not the organic solvents, are sometimes added to increase the density of water relative to the organic solvent. Cone bottomed tanks are the primary source of process wastewater, since they are used for initial treatment of spent solvents, for treatment of still bottoms, and sometimes in the product purification stage.

Fractional distillation units are a secondary source of process wastewater. About 60 percent of the NASR survey respondents use this process, which is used to separate mixed solvents. The separation process results in an aqueous discharge. Fractional distillation is sometimes used as a purification step in the solvent recovery process.

The average solvent recovery facility discharges 400 gallons of process wastewater per day. The estimate is based on data from ten solvent reclaimers with flows that range from 1 to 2,500 gallons per day (SAIC 1987a).

Data are available that can be used to quantitatively characterize solvent recovery process wastewater. Raw process wastewater has been analyzed at three facilities as a result of an EPA-Office of Research and Development (EPA-ORD) study and the current EPA-ITD study. One facility indirectly discharges process wastewater generated during the recovery of nonhalogenated, paint-related solvents. A second facility uses steam stripping to treat wastewater resulting from the recycling of halogenated and nonhalogenated solvents. The third facility recycles mixed solvents and contract hauls aqueous residuals. Descriptions and analytical results are discussed below for each of the facilities identified herein as Plants, A, B, and C.

Plant A

Plant A recovers 300,000 gallons per year of nonhalogenated paint-related solvents that were generated by the equipment manufacturing industry. These spent solvents are recovered without the benefit of initial treatment in either a flash still or a thin-film evaporator. No wastewater results from Plant A's processing of nonhalogenated solvents.

Plant A generates wastewater from the recovery of 100,000 gallons per year of halogenated solvents used by electronics and medical technologies manufacturers. After flash distillation, the solvent-water mixture is allowed to settle in a cone bottom tank. Water is drawn off the tank bottom, held in a storage tank, and periodically bled into the facility cooling tower. Blowdown from the cooling tower is discharged to a publicly-owned treatment work (POTW) along with sanitary and other nonprocess wastewater. The total discharge averages 315 gallons per day, of which 75 gallons are estimated to be process wastewater.

EPA-ORD sampled process wastewater from the flash still during two separate product runs in 1986 (Alliance 1986). This work was conducted to establish pollutant mass balances in support of air emissions regulations development. Plant personnel believe that the results of the first run are not representative of typical process wastewater characteristics, since:
(1) the ambient sampling temperatures were in excess of 100°F and approached the boiling point of the waste feed's main component, methylene chloride; and (2) plant personnel learned later that the waste feed was actually a still bottom generated elsewhere; hence, they no longer accept this waste. In the first run, the following parameters were reported in the wastewater: methylene chloride at 7,500 mg/l; 1,1,2-trichloro-1,2,2-trifluoroethane at 1,100 mg/l; and isopropanol at 68,000 mg/l. The second run was more typical and consisted of a 1,1,1-trichloroethane spent solvent. The resultant wastewater contained 9,400 mg/l of 1,1,1-trichloroethane. Analytical detection limits for the respective runs were on the order of 200 mg/l and no other organic parameters were reported to have been detected.

EPA-ITD sampled the process wastestream in 1986 as part of the current study. The process wastewater had been collected over a 1-week period in a storage tank prior to its discharge to a cooling tower. The sampled wastewater reflects the recovery of fluorocarbons, methylene chloride, and 1,1,1-trichloroethane.

Plant B

Plant B recovers spent solvents for reuse in fuel blends and for batch toll customers. Halogenated and nonhalogenated solvents are recovered in stills for reuse as solvents. The wastewater generated by these operations is small compared to the amount generated as a result of fuel blending operations. Received spent

solvents are initially treated by gravity separation and the combined plant process wastewaters are stored for a week prior to treatment. Oil/water separation and steam stripping is provided prior to the discharge of 260 gallons per day.

EPA-ORD sampled process wastewater discharged from the steam stripper (GCA 1986). During the test period, 1,1,1-trichloroethane was being processed. The only organic compound observed in the stripper effluent was 1,1,1-trichloroethane at 55,000 mg/l. No other organics were found; however, analytical method detection limits were on the order of 200 mg/l.

EPA-ITD, in 1987, obtained a sample of the process wastewater influent to the steam stripper. Plant personnel described the raw waste as a typical wastewater. An effluent sample also was obtained for the purpose of evaluating treatment effectiveness, a topic that is addressed in Section 6 of this report.

Plant C

Plant C recovers spent solvents, received in drums combining 60 percent nonhalogenated, 30 percent halogenated, and 10 percent miscellaneous solvents. Spent solvents also are received in tankers; however, no process wastewater is associated with the wastes. A wide range of industries are served and fuel blends are the primary destination of recovered products. The plant also recovers solvents on a batch toll basis and for the open market. Phase separations are accomplished by batch distillation, fractional distillation, and thin film evaporations. Process wastewater is comingled, stored, and shipped off-site for treatment and disposal if the specifications of the contract hauler are met. The wastewater volume averages 800 gallons per day.

EPA-ITD obtained a sample of process wastewater in 1987. The sample was obtained from a tank that held all process wastewater collected over the previous 2 weeks. The tank contained a flammable solvent layer (top), a solvent/water layer (middle), and a chlorinated solvent layer (bottom), and a representative sample of the contents of the entire tank was obtained. Plant personnel described the tank contents as not meeting the specifications of the contract hauler; therefore, the wastestream would be treated by fractional distillation. An effluent sample from the still was not available.

EPA-ITD Data

Samples collected by EPA-ITD are the best available for characterizing raw wastewater generated by solvent recovery processes. Process wastewaters were sampled at three different facilities in order to represent adequately the diversity of waste types. Plant A process wastewater was generated by the flash distillation of halogenated solvents used by the electronics

industry. Plant B process wastewater was primarily the result of initial treatment processes employed to treat mixed solvents destined for reuse in fuel blends. Plant C process wastewater is the result of initial treatment processes applied to nonhalogenated and halogenated solvents.

Samples collected from the three facilities were analyzed for conventional, nonconventional, and priority pollutants, as well as compounds on the ITD list of analytes. The discussion below focuses on the analytical fractions reported for all of the untreated, raw wastewater samples collected by ITD. The fractions are: (1) conventional and nonconventional, (2) metals, (3) extractable and volatile organics, and (4) pesticides/herbicides. A total of three raw wastewater samples was taken at the facilities. Two methods were used to determine mean concentrations for individual pollutants. The first method reflects the concentration of the pollutant when it is present in a sample and the calculation does not include the use of zero, or not detected, values. The second method reflects an industry average level and the calculation includes the use of zero, or not detected, values.

- Conventional and Nonconventional Parameters. Raw wastewaters exhibited a pH range of 3.6 to 9.5 and a similarly wide range for most of the parameters shown in Table 5-1. For example, oil and grease levels ranged from 205 to 97,000 mg/l, with an average of 34,400 mg/l. Similarly, TOC ranged from 540 to 300,000 mg/l, with an average of 111,000 mg/l. Consistently high concentrations are shown for BOD and COD. The mean total BOD_5 is 76,300 mg/l and the mean total COD is 145,000 mg/l.

- Metals. The data in Table 5-2 show high levels for numerous metals in the raw wastewater samples. Eight of the 27 metals were detected at average levels above 10 mg/l. These are aluminum, boron, calcium, iron, lead, magnesium, sodium, and zinc. In addition to the quantitative analyses, qualitative analyses were run to determine the presence of 41 additional elements. The other elements detected are shown in Table 5-3.

- Extractable and Volatile Organics. The data in Table 5-4 show that 43 organic compounds were detected in the wastewater samples. The compounds found at each of the three facilities sampled are 1,1,1-trichloroethane, acetone, methylene chloride, and trichloroethene. Compounds found at two of the three facilities are 2-butanone(MEK), ethylbenzene, isophorone, n-decane, p-dioxane, and toluene. The industry mean concentrations exceed 10 mg/l for 40 parameters and exceed 100 mg/l for 24 parameters. The total sum of toxic organics is the sum of all means and is equal to 23,000 mg/l.

TABLE 5-1. EPA-ITD SAMPLING PROGRAM
COMPARISON OF PROCESS WASTEWATER

Fraction: Conventionals and Nonconventionals

Sample Point: Raw Wastewater

Plant No.		A	B	C	
Episode No.		1134	1180	1181	
Sample No.		15367	15727	15731	Mean
Sample Date		Sep 19, 1986	Mar 20, 1987	Mar 31, 1987	
Flow, Gallons per Day		75	260	800	
Parameter	**Units**				
Ammonia	mg/l	NR	30.1	144	87
BOD_5, Total	mg/l	30000	153000	46000	76300
BOD_5, Dissolved	mg/l	18600	138000	39000	65200
Chloride	mg/l	1500	2830	12800	5710
COD, Dissolved	mg/l	71400	150000	108000	110000
COD, Total	mg/l	82100	218000	134000	145000
Dissolved Solids	mg/l	16000	156000	34600	68900
Fluoride	mg/l	120	8.6	1.4	43
Oil & Grease	mg/l	97000	205	6100	34400
Phenol	mg/l	4	17	175	65
Suspended Solids	mg/l	160	464	4170	1600
Suspended Vol Solids	mg/l	116	338	1900	785
TKN	mg/l	154	1060	279	498
Total Cyanide	mg/l	.76	3.5	7	4
Total Organic Carbon	mg/l	540	300000	32000	111000
Total Vol Solids	mg/l	4140	8319	20663	11000
pH		9.5	7.6	3.6	-

Note: NR indicates no data reported
mg/l = milligrams per liter
Mean = mean of detectd values.
For example, mean ammonia = (30.1 + 144)/2=87

TABLE 5-2. EPA-ITD SAMPLING PROGRAM
COMPARISON OF PROCESS WASTEWATER

Fraction: Metals

Sample Point: Raw Wastewater

Plant No.		A	B	C	
Episode No.		1134	1180	1181	
Sample No.		15367	15727	15731	Mean
Sample Date:		Sep 19, 1986	Mar 20, 1987	Mar 31, 1987	
Flow, Gallons per Day		75	260	800	
Parameter	**Units**				
Aluminum	µg/l	280	2120	31800	11400
Antimony	µg/l	117	447	1290	618
Arsenic	µg/l	9	30	176	72
Barium	µg/l	55	700	1290	682
Beryllium	µg/l	ND-1	ND-5	85	85
Boron	µg/l	710	26000	14200	13600
Cadmium	µg/l	56	79	6010	2050
Calcium	µg/l	49000	59400	6020000	2040000
Chromium	µg/l	17	3820	6500	3450
Cobalt	µg/l	29	2050	1620	1230
Copper	µg/l	790	1220	13300	5100
Iron	µg/l	6600	7220	516000	177000
Lead	µg/l	450	3210	46200	16600
Magnesium	µg/l	7500	619	51600	19900
Manganese	µg/l	170	619	13500	4760
Mercury	µg/l	3	20	22	15
Molybdenum	µg/l	57	1040	496	531
Nickel	µg/l	430	656	22100	7730
Selenium	µg/l	50	166	25	80
Silver	µg/l	ND-1	13	29	21
Sodium	µg/l	880000	5740000	1310000	2640000
Thallium	µg/l	ND-10	ND-10	ND-10	ND
Tin	µg/l	730	686	1110	842
Titanium	µg/l	50	50	50	50
Vanadium	µg/l	ND-2	50	147	99
Yttrium	µg/l	ND-10	50	50	50
Zinc	µg/l	4800	8900	261000	91600

Note: ND = Not detected above detection limit. Detection limit shown.
µg/l = micrograms per liter
Mean = Mean of detected values. Neither ND values nor zero are used in the calculation. For example, mean silver = (13 + 29)/2=21

TABLE 5-3. EPA-ITD SAMPLING PROGRAM COMPARISON OF PROCESS WASTEWATER

Fraction: Superscan Metals

Sample Point: Raw Wastewater

Plant No.	A	B	C
Episode No.	1134	1180	1181
Sample No.	15367	15727	15731
Sample Date	Sep 19, 1986	Mar 20, 1987	Mar 31, 1987
Parameter			
Bismuth	ND	ND	ND
Cerium	ND	ND	Detected
Dysprosium	ND	ND	ND
Erbium	ND	ND	ND
Europium	ND	ND	ND
Gadolinium	ND	ND	ND
Gallium	ND	ND	ND
Germanium	ND	ND	ND
Gold	ND	ND	ND
Hafnium	ND	ND	ND
Holminum	ND	ND	ND
Indium	ND	ND	ND
Iodine	Detected	Detected	Detected
Iridium	Detected	Detected	Detected
Lanthanum	ND	ND	Detected
Lithium	ND	Detected	Detected
Lutetium	ND	ND	Detected
Neodymium	ND	ND	Detected
Niobium	ND	ND	ND
Osmium	ND	ND	ND
Palladium	ND	ND	ND
Phosphorus	Detected	Detected	Detected
Platinum	ND	ND	Detected
Potassium	Detected	Detected	Detected
Praseudymium	ND	ND	ND
Rhenium	ND	ND	ND
Rhodium	ND	ND	ND
Ruthenium	ND	ND	ND
Samarium	ND	ND	ND
Scandium	ND	ND	ND
Silicon	Detected	Detected	Detected
Strontium	Detected	Detected	Detected
Sulfur	Detected	Detected	Detected

TABLE 5-3. EPA-ITD SAMPLING PROGRAM COMPARISON OF PROCESS WASTEWATER (Continued)

Fraction: Superscan Metals

Sample Point: Raw Wastewater

Plant No.	A	B	C
Episode No.	1134	1180	1181
Sample No.	15367	15727	15731
Sample Date	Sep 19, 1986	Mar 20, 1987	Mar 31, 1987
Parameter			
Tantalum	ND	ND	ND
Tellurium	ND	ND	ND
Terbium	ND	ND	ND
Thorium	ND	ND	ND
Thulium	ND	ND	ND
Tungston	ND	ND	Detected
Uranium	ND	ND	Detected
Ytterbium	ND	ND	ND
Zirconium	ND	ND	ND

Note: ND indicates not detected

TABLE 5-4. EPA-ITD SAMPLING PROGRAM
COMPARISON OF PROCESS WASTEWATER

Fraction: Extractable and Volatile Organics

Sample Point: Raw Wastewater

Plant No.		A	B	C	
Episode No.		1134	1180	1181	
Sample No.		15367	15727	15731	Mean
Sample Date		Sep 19, 1986	Mar 20, 1987	Mar 31, 1987	
Flow, Gallons per Day		75	260	800	
Parameter	**Units**				
1,1,1,-Trichloroethane	µg/l	209830	3524	33103	82200
1,2,4-Trichlorobenzene	µg/l	ND-100	ND-10000	248019	248000
1,2-Dichlorobenzene	µg/l	ND-100	ND-10000	3162420	3160000
1,2-Diphenylhydrazine	µg/l	ND-200	ND-20000	238308	238000
1,3-Dichlorobenzene	µg/l	ND-100	ND-10000	36534	36500
1,4-Dichlorobenzene	µg/l	ND-100	ND-10000	76607	76600
2,4-Dimethylphenol	µg/l	ND-100	ND-10000	51341	51300
2-Butanone (MEK)	µg/l	52471	ND-50	1460400	756000
2-Chlorophenol	µg/l	ND-100	ND-10000	44460	44400
2-Methylnaphthalene	µg/l	ND-10	ND-10000	142508	143000
4-Methyl-2-Pentanone	µg/l	ND-50	ND-10	5155390	516000
Acetone	µg/l	549680	18154300	1070390	6590000
Alpha-Terpineol	µg/l	ND-100	47727	ND-10000	47700
Benzene	µg/l	ND-100	16	ND-10000	16
Biphenyl	µg/l	ND-100	ND-10000	29020	29000
Bis(2-Ethylhexyl)Phthalate	µg/l	ND-100	ND-10000	1138370	1140000
Butyl Benzyl Phthalate	µg/l	ND-100	ND-10000	178183	178000
Chloroform	µg/l	ND-100	ND-10	40529	40500
Di-N-Butyl Phthalate	µg/l	ND-100	ND-10000	205853	206000
Di-N-Octyl Phthalate	µg/l	ND-100	ND-10000	259699	260000
Ethylbenzene	µg/l	2191	688	ND-10000	1440
Fluoranthene	µg/l	ND-100	ND-10000	31580	31600
Fluorene	µg/l	ND-100	ND-10000	20990	21000
Isobutyl Alcohol	µg/l	ND-10	ND-10	165184	165000
Isophorone	µg/l	ND-100	12715	230639	122000
Longifolene	µg/l	833	ND-10000	ND-10	833
Methylene Chloride	µg/l	663040	1540990	296310	833000
N,N-Dimethylformamide	µg/l	ND-10	ND-1000	106559	107000
N-Decane (N-C10)	µg/l	927	ND-10000	454722	228000
N-Eicosane (N-C20)	µg/l	ND-100	ND-10000	228717	229000
N-Hexadecane (N-C16)	µg/l	ND-100	ND-10000	574539	575000
N-Tetradecane (N-C14)	µg/l	ND-100	ND-10000	359062	359000
Naphthalene	µg/l	ND-100	ND-10000	345200	345000
O-Cresol	µg/l	ND-10	ND-10000	33069	33000
P-Cresol	µg/l	ND-10	ND-10000	48238	48200
P-Dioxane	µg/l	ND-100	1120390	7187800	4150000

TABLE 5-4. EPA-ITD SAMPLING PROGRAM
COMPARISON OF PROCESS WASTEWATER
(Continued)

Fraction: Extractable and Volatile Organics

Sample Point: Raw Wastewater

Plant No.		A	B	C	
Episode No.		1134	1180	1181	
Sample No.		15367	15721	15731	Mean
Sample Date		Sep 19, 1986	Mar 20, 1987	Mar 31, 1987	
Flow, Gallons per Day		75	260	800	
Parameter	**Units**				
Phenanthrene	µg/l	ND-100	ND-10000	46833	46800
Phenol	µg/l	ND-100	ND-10000	154046	154000
Pyrene	µg/l	ND-100	ND-10000	10766	10800
Styrene	µg/l	ND-100	ND-10000	202054	202000
Tetrachloroethene	µg/l	1350350	ND-10	ND-10000	1350000
Toluene	µg/l	555	ND-10	43326	21900
Trichloroethene	µg/l	8495	1278	20474	10100

Note: ND indicates not detected above detection limit. Detection limit shown.
µg/l = micrograms per liter
Mean indicates mean of detected values. Calculation does not include not detected or zero values. For example, mean toluene = (555 + 43326)/2=21900

- Pesticides/Herbicides. Wastewater at Plant A was analyzed for 100 pesticide/herbicide compounds and none were detected.

The EPA-ITD data for solvent recycling of raw wastewaters are presented in this report as representative of the industry wastestreams. The data represent halogenated and nonhalogenated compounds recycled for use in fuel blends and recycled for reuse as solvents. No other data are available that are representative of wastewater that has been separated from spent solvents.

5.3.2 Cooling and Miscellaneous Wastewater

Noncontact cooling water is used in solvent recovery operations to cool pumps and condensers. As such, no process contact is usually associated with cooling water discharges from cooling towers and once-through cooling. The volume of cooling water depends on the degree to which distillation is used at a particular facility. A plant that only provides initial treatment for solvents destined for reuse in fuel blends would not require cooling. On the other hand, a plant that distills spent solvents for reuse would require cooling for condensing product vapors. The Agency collected cooling water flow information from five plants that showed a flow range of from 60 to 35,000 gallons per day and an average of 11,000 gallons per day (SAIC 1987c).

EPA-ITD collected cooling water samples from two solvent recovery facilities, identified here as Plants D and E. The Plant D discharge consists of noncontact cooling water and steam condensate (87 percent) pump cooling water (8 percent) and sanitary wastewater (5 percent). Plant D recovers nonhalogenated solvents (85 percent) and halogenated solvents (15 percent) with a thin-film evaporator. The Plant D flow is 35,000 gallons per day. The Plant E discharge consists of noncontact cooling water, boiler blowdown, and a small amount of sanitary wastewater that totals 30,000 gallons per day.

Analytical data for the two facilities are summarized in Table 5-5 and include permit monitoring data from Plant D. BOD_5, COD, and TOC levels are very high for these noncontact cooling waters. BOD_5 averages 918 mg/l, COD is 3503 mg/l, and TOC is 113 mg/l. Metals are present at fairly low levels with respect to process wastewater except for iron. Eleven organics were detected at Plant E, with acetone, benzene, methylene chloride, 1,1,2-trichloroethane, and 1,1,2,2-tetrachlorethane having mean industry concentrations greater than 1 mg/l. Four organics were found in an EPA-ITD sample taken at Plant D and only one was greater than 100 µg/l. Permit monitoring data supplied by Plant D revealed eight organic compounds present in the discharge. The total toxic organics in the three samples averaged 440 mg/l per sample.

TABLE 5-5. EPA-ITD SAMPLING PROGRAM: COOLING WATER AND COMINGLED NONPROCESS WASTEWATER

Fraction	Parameter(1)	Plant D Permit Monitoring	Plant D Sample #15338	Plant E Sample #15015	Mean
Conventionals	BOD-5, mg/l	2,240	270	246	919
	COD, mg/l	9,680	370	460	3,503
	TOC, mg/l	ND	100	125	113
	Total Suspended Solids, mg/l	26	60	59	48
	Oil and Grease, mg/l	10	1.5	ND	5.8
Metals	Cadmium	348	ND	8	178
	Chromium	5,000	6	ND	2,503
	Iron	198,000	8,100	5,460	70,520
	Lead	2,900	5	ND	1,475
	Mercury	ND	ND	6.1	6.1
	Strontium	ND	ND	150	150
	Zinc	ND	120	33	77
Organics	Acetone	ND	ND	415,110	415,110
	Benzene	240	ND	26,130	13,185
	Biphenyl	ND	ND	85	85
	Chlorobenzene	215	ND	ND	215
	Chloroethane	17	ND	ND	17
	1,1-Dichloroethane	12	ND	ND	12
	Trans-1,2-Dichloroethene	9	ND	ND	9
	Diphenyl Ether	ND	ND	223	223
	Ethylbenzene	4	ND	ND	4
	Methylene Chloride	ND	ND	5,319	5,319
	Naphthalene	ND	ND	15	15
	Phenol	ND	ND	129	129
	Thioxanthone	ND	27	ND	27
	Toluene	42	ND	438	240
	Trichloroethane	ND	81	352	217
	Tripropyleneglycol methylether	ND	775	ND	775
	1,1,1-Trichloroethene	ND	69	ND	69
	1,1,2-Trichloroethane	ND	ND	2,090	2,090
	1,1,2,2-Tetrachloroethane	ND	ND	2,090	2,090
	Vinyl Chloride	17	ND	ND	17
	Total Toxic Organics	556	952	451,981	440,000

Note:

(1) Concentrations expressed in µg/l, unless otherwise noted.
mg/l = milligrams per liter
µg/l = micrograms per liter
ND = not detected
Mean = Mean of detected values. Calculation does not include not detected or zero values. For example, mean TOC = (100 + 125)/2=113.

When compared to noncontact cooling water discharged in other industries, the measured pollutant concentrations are significantly higher. Noncontact cooling water should contain no detectable toxic organics. Furthermore, the conventional pollutants BOD_5, COD, and TOC are observed to be at very high levels compared to typical freshwater supplies. Effluent limitations guidelines for the Petroleum Refining Point Source Category limit TOC in noncontact cooling water to 5 mg/l. The data suggest that control of noncontact cooling water may be necessary to minimize the discharge of oxygen-demanding pollutants and toxic organics.

5.4 RESIDUALS DISPOSAL

Solvent recovery solid residuals include wastewater treatment sludges, still bottoms, and incinerator ash. Since end-of-pipe wastewater treatment technologies are not common in this industry, little information is available to characterize wastewater treatment sludges. No data are available to characterize ash resulting from the burning of still bottoms and aqueous solvent wastes in furnaces.

Information has been collected that can be used to characterize still bottoms. NASR (1982) reports that 27 percent of spent solvents distilled are not recovered. This residue, or still bottoms, is composed of fats, oils, emulsions, organic solvents, solids, and water. Still bottoms are typically blended with fuels because of their high Btu value. Low levels of water are usually acceptable in the fuel mixture. Unacceptable still bottoms are incinerated on-site or contract handled. The Agency is unaware of any solvent reclaimer that discharges still bottoms directly or indirectly to the Nation's waters.

A solvent reclaimer, identified in this report as Plant F, submitted data that show proportions of various chemical fractions contained in two still bottoms samples. Still bottoms are generated at Plant F by a thin-film evaporator. Spent solvent types are limited to halogenated solvents used in machinery degreasing and in the electronics industry. Table 5-6 shows the result of the facility's in-house testing. The first sample is composed mostly of organic compounds and water. About three-quarters of the second sample is chlorinated and fluorinated compounds.

EPA-ITD obtained a still bottom sample from Plant A for analysis. The sample is the residual resulting from thin-film evaporation of nonhalogenated (85 percent) and halogenated (15 percent) solvents. Table 5-7 shows conventional and nonconventional pollutants in the sample. The very high concentrations of organics did not allow an accurate determination of BOD, ammonia, TKN, dissolved COD, and some solids. The total COD measured equaled 143 percent of the sample mass. Oil and grease

TABLE 5-6. STILL BOTTOMS GENERATED AT PLANT F

Parameter	Weight by Percent (%)	
	Sample 1	Sample 2
Water	40-50	2-6
Oil	10-15	15-20
Alcohols	4-8	5-8
Hydrocarbons	3-5	2-4
Ketones	2-3	2-5
Chlorinated	25-30	35-45
Fluorinated	10-15	25-35
Resins and Solids	3-6	1-4
Specific Gravity		
Layer 1	1.04	1.10
Layer 2	1.14	--
PH, S.U.	7-9.0	8.0-8.5
Flash Point, °F	130	120

TABLE 5-7. EPA-ITD SAMPLING PROGRAM STILL BOTTOMS

Fraction: Conventionals and Nonconventionals

Sample Point: Still Bottom

Plant No.		A
Episode No.		1129
Sample No.		15342
Sample Date		Jul 24, 1986
Parameter	**Units**	
Chloride	mg/kg	3300
COD, Total	mg/kg	1430000
Fluoride	mg/kg	14100
Oil & Grease	mg/kg	188000
Phenol	mg/kg	2.06
Total Cyanide	mg/kg	94
Total Vol Solids	mg/kg	280000

Note: mg/kg = milligrams per kilogram, wet basis.

constituted 18.8 percent of the sample and total volatile solids constituted 28 percent.

Metals are reported in mg/kg in Table 5-8 for the still bottoms sample. Lead is the most significant compound and constitutes over 5 percent of the sample. Aluminum, barium, and zinc are the next most significant metals and collectively constitute 1 percent of the sample mass.

Thirteen extractable and volatile organic compounds were measured in the still bottoms sample, as shown in Table 5-9. Each compound was present in high concentrations and 2-butanone (MEK) was highest at 7,562 mg/l. Acetone, ethylbenzene, and toluene had concentrations of greater than 100 mg/l.

Dioxins and furans measured in the sample are shown in Table 5-10. Of the nine compounds measured, OCDF had the highest concentration at 4,390 parts per trillion (ppt).

The still bottom sample was subjected to the Toxicity Characteristic Leaching Procedure (TCLP). This procedure attempts to identify compounds that could potentially leach from solid and semi-solid matrices in the waste. Tables 5-11 and 5-12 show the results of TCLP analyses for metals and extractable and volatile organics. Zinc is the only toxic metal measured at a significant level. The three organic compounds identified in the TCLP extract that were not identified by traditional methods are alpha-terpineol, isophorone, and thioxanthone. Only 2-butanone (MEK) was present at a concentration greater than 100 mg/l.

The still bottoms data discussed above indicate that high levels of organics and metals are present in still bottoms. This should be the case, since still bottoms are the solid and nondistillable residue that remain after distillation. The presence of dioxin and furan compounds was confirmed and levels are significant.

5.5 SUMMARY

The following summarizes the major points that were discussed in this section:

- The average solvent recycler handles 0.8 million gallons of spent solvents annually. Process wastewater discharges average 400 gallons per day and result primarily from the physical separation of water from spent solvents.

- Industry raw wastewater is characterized by very high concentrations of conventional, nonconventional, metal, and organic pollutants. The data shown below for

TABLE 5-8. EPA-ITD SAMPLING PROGRAM STILL BOTTOMS

Fraction: Metals

Sample Point: Still Bottom

Plant No.		A
Episode No.		1129
Sample No.		15342
Sample Date		Jul 24, 1986
Parameter	**Units**	
Aluminum	mg/kg	6560
Antimony	mg/kg	117
Arsenic	mg/kg	6
Barium	mg/kg	4510
Beryllium	mg/kg	2
Boron	mg/kg	195
Cadmium	mg/kg	112
Calcium	mg/kg	3530
Chromium	mg/kg	1390
Cobalt	mg/kg	36
Copper	mg/kg	507
Iron	mg/kg	3400
Lead	mg/kg	55600
Magnesium	mg/kg	1060
Manganese	mg/kg	55
Mercury	mg/kg	6.5
Molybdenum	mg/kg	1160
Nickel	mg/kg	58
Selenium	mg/kg	6
Silver	mg/kg	.3
Sodium	mg/kg	1080
Thallium	mg/kg	6
Tin	mg/kg	94
Titanium	mg/kg	97
Vanadium	mg/kg	15
Yttrium	mg/kg	15
Zinc	mg/kg	4650

Note: mg/kg = milligrams per kilogram, wet basis.

TABLE 5-9. EPA-ITD SAMPLING PROGRAM STILL BOTTOMS

Fraction: Extractable and Volatile Organics

Sample Point: Still Bottom

Plant No.		A
Episode No.		1129
Sample No.		15342
Sample Date		Jul 24, 1986
Parameter	Units	
1,1,1-Trichloroethane	mg/kg	15422
2-Butanone (MEK)	mg/kg	7561900
2-Chloronaphthalene	mg/kg	4927
Acetone	mg/kg	110364
Benzoic Acid	mg/kg	18520
Chlorobenzene	mg/kg	602
Ethylbenzene	mg/kg	298600
Methyl Methacrylate	mg/kg	1379
Methylene Chloride	mg/kg	10299
N-Decane (N-C10)	mg/kg	6560
Phenol	mg/kg	1049
Toluene	mg/kg	229730
Trichloroethene	mg/kg	5779

Note: mg/kg = milligrams per kilogram, wet basis.

TABLE 5-10. EPA-ITD SAMPLING PROGRAM STILL BOTTOMS

Fraction: Dioxins/Furans

Sample Point: Still Bottom

Plant No.		A
Episode No.		1129
Sample No.		15342
Sample Date		Jul 24, 1986
Parameter	**Units**	
1234678-HpCDF	ppt	259.87
1234789-HpCDF	ppt	491.98
12378-PCDD	ppt	16.08
123789-HxCDD	ppt	9.39
234678-HxCDF	ppt	58.47
2378-TCDD	ppt	28.10
OCDF	ppt	4390.64
Total HxCDF	ppt	132.85
Total PCDD	ppt	16.08

Note: ppt = parts per trillion, wet basis.

TABLE 5-11. EPA-ITD SAMPLING PROGRAM
STILL BOTTOMS - TCLP ANALYSIS

Fraction: Metals

Sample Point: Still Bottom

Plant No.		A
Episode No.		1129
Sample No.		15342
Sample Date		Jul 24, 1986
Parameter	**Units**	
Sodium	µg/l	1640000
Thallium	µg/l	20
Tin	µg/l	155
Titanium	µg/l	50
Vanadium	µg/l	50
Yttrium	µg/l	50
Zinc	µg/l	129000

Note: µg/l = micrograms per liter, wet basis.

TABLE 5-12. EPA-ITD SAMPLING PROGRAM
STILL BOTTOMS - TCLP ANALYSIS

Fraction: Extractable and Volatile Organics

Sample Point: Still Bottom

Plant No.		A
Episode No.		1129
Sample No.		15342
Sample Date		Jul 24, 1986
Parameter	**Units**	
1,1,1-Trichloroethane	µg/l	5560
2-Butanone (MEK)	µg/l	13573300
2-Chloronaphthalene	µg/l	4976
Alpha-Terpineol	µg/l	2658
Chlorobenzene	µg/l	60
Ethylbenzene	µg/l	10901
Isophorone	µg/l	6082
Methylene Chloride	µg/l	3470
Thioxanthone	µg/l	38212
Toluene	µg/l	63928
Trichloroethene	µg/l	113

Note: µg/l = micrograms per liter, wet basis.

selected parameters are representative of a typical industry process wastewater:

Parameter	Concentration (mg/l)
BOD_5	76,300
COD	145,000
Oil and Grease	34,400
TOC	111,000
Iron	177
Lead	17
Zinc	92
Acetone	6,590
Methylene Chloride	833
1,1,1-Trichloroethane	82
Trichloroethene	10
Total Toxic Organics	23,000

- Forty-three extractable and volatile organics were detected in industry raw wastewaters. Of these, 40 have industry mean concentrations that exceeded 10 mg/l, and 24 exceeded 100 mg/l.

- Noncontact cooling water discharges average 11,000 gallons per day and contain significant levels of pollutants. The data below show industry mean concentrations:

Parameter	Concentration (mg/l)
BOD_5	919
COD	3500
TOC	75
Total Toxic Organics	440

- Still bottoms are highly concentrated mixtures of solvents, oils, greases, and solids. Nine dioxin and furan compounds were found in still bottoms samples. No discharges of still bottoms to the Nation's waters are known to occur routinely.

6. CONTROL AND TREATMENT TECHNOLOGY

The purpose of this section is to describe the types of control and treatment technologies used in the solvent recycling industry. The pollutant removal effectiveness of these technologies also is discussed. In addition, the control technology that allows most recyclers to achieve zero discharge of process wastewater is discussed.

6.1 ZERO DISCHARGE METHODS

The solvent recovery industry does not employ any one predominant technology to treat wastewater. In fact, few facilities discharge process wastewater. The U.S. Environmental Protection Agency (EPA) contacted recovery facilities by telephone for the purpose of verifying discharge status. Of the 107 respondents that generate wastewater, 81 percent reported zero discharge of process wastewater. Zero discharge was achieved by off-site disposal at 31 plants, by fuel blending or incineration at 30 plants, by evaporation at 11 plants, by deep well injection at 4 plants, and by landfilling at 2 facilities. Five respondents reported that their solvent recovery operation generated no wastewater and three return wastewater to the generator (SAIC 1987d).

6.2 IN-PLANT WASTEWATER CONTROL

Few opportunities exist for wastewater minimization in solvent recovery processes. The volume of water contained in received spent solvents is controlled at the site of the generator. An incentive to minimize the water volume exists, since the recovery cost of the generator is based on a per gallon charge. Flash distillation is the only process in which water (steam) is added. This distillation technology is not in common use and steam usage is controlled by physical/chemical equilibria.

Facilities with fractional distillation units sometimes use these systems to either recover solvents from dilute aqueous solutions or to improve water quality prior to discharge. This technology is employed primarily to recover products and is not generally used as a wastewater treatment technology. The Agency did not collect any samples to assess the performance of fractional distillation. A facility that recovers halogenated solvents reports that the solvent content of its wastewater is reduced from 5 to 0.5 percent by fractional distillation.

6.3 WASTEWATER TREATMENT

The Agency contacted solvent recycling facilities for the purpose of determining what end-of-pipe treatment technologies are in place (SAIC 1987a). Of the 21 facilities that are known to

discharge wastewater, 10 do not treat wastewater. Four facilities circulate their wastewater through a cooling tower prior to discharge. Three plants use steam stripping. One plant uses carbon filtration, while another uses carbon after biological treatment. Another facility uses a cooling tower followed by chemical oxidation. The last plant uses an oil/water separator. Only half of the known dischargers have any end-of-pipe treatment in place and no single technology predominates.

EPA's Industrial Technology Division (EPA-ITD) made presampling visits to three solvent recyclers in 1986 and 1987 that had end-of-pipe treatment technology in-place. One plant used steam stripping, but sampling points were not accessible. A second plant was believed to use air stripping, but since this form of treatment was being provided by a cooling tower that emitted uncontrolled pollutants to the air, it was not sampled. The Agency did obtain samples of steam stripper influent and effluent from Plant B.

Steam stripper pollutant removals are calculated and shown in Tables 6-1, 6-2, and 6-3 for conventionals and nonconventionals, metals, and extractable and volatile organics, respectively. Poor removals observed for some constituents in the grab samples, such as oil and grease and some volatile organics, can be attributed to sampling technique. However, this is unlikely, since grab samples were taken simultaneously at the influent and effluent sampling points and the system had a short detention time of less than 3 minutes. Also, similarly poor removals were observed for constituents in the remaining composite samples. In addition to the data shown, only one dioxin/furan compound was detected. The isomer OCDD was present in the treated effluent at 2.96 parts per trillion (ppt).

6.4 BEST DEMONSTRATED AVAILABLE TECHNOLOGY

Five treatment technologies are demonstrated for wastewaters containing F001-F005 spent solvents (EPA 1986a). These are carbon adsorption, steam stripping, biological treatment, wet air oxidation, and air stripping. Incineration and fuel substitution were not demonstrated for wastewaters containing F001-F005 spent solvents. The demonstrated technologies formed the basis for development of Best Demonstrated Available Technology (BDAT) treatment standards for solvent-bearing wastewater destined for land disposal.

The data base from which the BDAT standards were developed is composed of treatment performance data for the demonstrated technologies. These data were abstracted from the Organic Chemicals, Plastics, and Synthetic Fibers (OCPSF) Industries Data Base; the Pharmaceuticals Industry Data Base; and the Iron and Steel Manufacturing Data Base. In addition, the Agency collected data and information from numerous bench-, pilot-, and full-scale studies.

TABLE 6-1. EPA-ITD SAMPLING PROGRAM
STEAM STRIPPING PERFORMANCE

Fraction: Conventionals and Nonconventionals

Sample Point:		Raw Wastewater	Treated Effluent	
Plant No.		B	B	
Episode No.		1180	1180	
Sample No.		15727	15728	Percent
Sample Date		Mar 20, 1987	Mar 20, 1987	Removed
Parameter	Units			
Ammonia	mg/l	30.1	22.1	27
BOD-5, Total	mg/l	153000	105000	31
BOD-5, Dissolved	mg/l	138000	84000	39
Chloride	mg/l	2830	2660	6
COD, Dissolved	mg/l	150000	155000	0
COD, Total	mg/l	218000	247000	0
Dissolved Solids	mg/l	156000	148000	5
Fluoride	mg/l	8.6	6	30
Oil & Grease	mg/l	205	3050	0
Phenol	mg/l	17	18.8	0
Sulfide	mg/l	.448	.744	0
Suspended Solids	mg/l	464	276	41
Suspended Vol Solids	mg/l	338	200	41
TKN	mg/l	1060	1080	0
Total Cyanide	mg/l	3.5	2	43
Total Organic Carbon	mg/l	300000	270000	10
Total Vol Solids	mg/l	8319	5228	37

Note: mg/l = milligrams per liter

TABLE 6-2. EPA-ITD SAMPLING PROGRAM
STEAM STRIPPING PERFORMANCE

Fraction: Metals

Sample Point:	Raw Wastewater	Treated Effluent	
Plant No.	B	B	
Episode No.	1180	1180	
Sample No.	15727	15728	Percent
Sample Date	Mar 20, 1987	Mar 20, 1987	Removed
Parameter			
Aluminum	2120	1200	43
Antimony	447	384	14
Arsenic	30	10	67
Barium	700	726	0
Beryllium	5	5	0
Boron	26000	23400	10
Cadmium	79	60	24
Calcium	59400	54100	9
Chromium	3820	3210	16
Cobalt	2050	1850	10
Copper	1220	731	40
Iron	7220	5020	30
Lead	3210	2270	29
Magnesium	619	26900	0
Manganese	619	547	12
Mercury	20	20	0
Molybdenum	1040	921	11
Nickel	656	592	10
Selenium	166	136	18
Silver	13	5	62
Sodium	5740000	3240000	44
Thallium	10	10	0
Tin	686	568	17
Titanium	50	50	0
Vanadium	50	50	0
Yttrium	50	50	0
Zinc	8900	7270	18

Note: All concentrations expressed in µg/l(micrograms per liter).

TABLE 6-3. EPA-ITD SAMPLING PROGRAM
STEAM STRIPPING PERFORMANCE

Fraction: Extractable and Volatile Organics

Sample Point:	Raw Wastewater	Treated Effluent	
Plant No.	B	B	
Episode No.	1180	1180	
Sample No	15727	15728	Percent
Sample Date	Mar 20, 1987	Mar 20, 1987	Removed
Parameter			
1,1,1-Trichloroethane	3524	ND	99
2-Butanone (MEK)	ND	1586260	0
4-Methyl-2-Pentanone	ND	131	0
Acetone	18154300	15477800	15
Allyl Alcohol	ND	36	0
Alpha-Terpineol	47727	ND	99
Benzene	16	47	0
Ethylbenzene	688	ND	99
Isophorone	12715	ND	99
Methylene Chloride	1540990	186702	88
P-Dioxane	1120390	767180	32
Trichloroethene	1278	1264	1

Note: ND indicates value not detected above detection limit
All concentrations expressed in µg/l(micrograms per liter).

The treatment standards imposed by the land disposal regulations are shown in Table 6-4. These standards apply to aqueous solutions as well as to Toxicity Characteristic Leaching Procedure (TCLP) extracts from solids. The standards address all of the 10 mostly widely used solvents shown in Table 4-3. These are xylene, methanol, toluene, methylene chloride, methyl ethyl ketone, tetrachloroethylene, trichloroethylene, 1,1,1-trichloroethane, acetone, and methyl isobutyl ketone.

6.5 SUMMARY

The following summarizes the major points that were discussed in this section:

- Zero discharge of process wastewater is achieved by 81 percent of the industry. Contract hauling, fuel blending and incineration are the primary zero discharge technologies.

- Only half of the discharging facilities treat their process wastewater prior to discharge. No single treatment technology prevails among dischargers.

TABLE 6-4. BDAT TREATMENT STANDARDS
(AS CONCENTRATIONS IN THE TREATMENT RESIDUAL EXTRACT)

Constituent	Wastewaters Containing Spent Solvents (mg/l)	Nonwastewater Spent Solvent Wastes (mg/l)
Acetone	0.05	0.59
n-Butyl alcohol	5.0	5.0
Carbon disulfide	1.05	4.81
Carbon tetrachloride	0.05	0.96
Chlorobenzene	0.15	0.05
Cresols (cresylic acid)	2.82	0.75
Cyclohexanone	0.125	0.75
1,2-dichlorobenzene	0.65	0.125
Ethyl acetate	0.05	0.75
Ethylbenzene	0.05	0.053
Ethyl ether	0.05	0.75
Isobutanol	5.0	5.0
Methanol	0.25	0.75
Methylene chloride	0.20	0.96
Methylene chloride generated at pharmaceuticals plants	12.7	0.96
Methyl ethyl ketone	0.05	0.75
Methyl isobutyl ketone	0.05	0.33
Nitrobenzene	0.66	0.125
Pyridine	1.12	0.33
Tetrachloroethylene	0.079	0.05
Toluene	1.12	0.33
1,1,1-Trichloroethane	1.05	0.41
1,1,2-Trichloro-1,2,2-trifluoroethane	1.05	0.96
Trichloroethylene	0.062	0.091
Trichlorofluoromethane	0.05	0.96
Xylene	0.05	0.15

Source: U.S. EPA 1986a

7. COST OF WASTEWATER CONTROL AND TREATMENT

The purpose of this section is to describe appropriate technology and costs for controlling industry wastewater discharges. An economic assessment of possible regulations affecting the solvent recovery industry is presented.

7.1 PROCESS WASTEWATER

The average process wastewater volumes discharged by solvent reclaimers are low in comparison to volumes economically treated by typical wastewater treatment technologies. The daily process wastewater flow ranges between 25 to 1,500 gallons, with an average facility discharging 400 gallons. Approximately 81 percent of the industry achieves zero discharge of process wastewater through the use of fuel blending, incineration, evaporation, contract hauling, and land disposal. The tendency to use zero discharge technologies is related to: (1) the availability of in-plant methods such as fuel blending and evaporation, and (2) the economics of contract hauling when compared to end-of-pipe treatment.

In a study conducted by the U.S. Environmental Protection Agency, Industrial Technology Division (EPA-ITD) for the pesticide formulating and packaging industry, a flow of 750 gallons per day was shown to be the economic limit for contract hauling of solvent-bearing wastewater (EPA 1985b). Compliance costs for proposed zero discharge effluent limitations were based on contract hauling for plants that discharged less than 750 gallons per day. Plants that discharged more than 750 gallons per day were shown to more economically achieve compliance by installing end-of-pipe treatment to achieve nondetectable pollutant levels. The treatment system included pumping, equalization, steam stripping, neutralization, dual media filtration, carbon adsorption, carbon regeneration, and incineration.

Contract hauling is an appropriate model technology for the purpose of determining the industry cost of complying with process wastewater effluent guidelines. This conclusion is based on the following information: 81 percent of the industry currently achieves zero discharge, and the average plant discharges 400 gallons per day, which is less than the 750 gallon flow shown to be economically contract-hauled by the pesticides industry.

Table 7-1 shows contract hauling costs for wastewater discharge flows of 25, 400, and 1,500 gallons per day. All cost data are abstracted from the Development Document for Effluent Limitations Guidelines and Standards for the Pesticide Point Source Category (USEPA 1985b).

TABLE 7-1. CONTRACT HAULING COSTS FOR PROCESS WASTEWATER

	Wastewater Flow (Gallons per day)		
	25	400	1,500
Capital Cost[a]	$20,000	$20,000	$20,000
Annual Cost[b]	$16,250	$260,000	$975,000

[a] Capital costs include piping, pumps, and a 5,000-gallon storage tank.

[b] Annual costs are based on 260 operating days per year and a contract hauling cost of $2.50 per gallon.

7.2 COOLING AND MISCELLANEOUS WASTEWATER

Sources of noncontact cooling water generated at solvent reclaimers are similar to sources in other industries. Solvent reclaimers use the same type of heat exchange equipment that is found in the organic chemicals, plastics, and synthetic fibers (OCPSF) and petroleum industries. This equipment includes condensers, pumps, and cooling towers. The spent solvents reprocessed by solvent reclaimers are manufactured in the OCPSF and petroleum industries. Since similar equipment is used and similar products are processed, the noncontact cooling waters discharged by the solvent recovery, OCPSF, and petroleum industries should contain comparable levels of pollutants. The cooling and miscellaneous wastewaters sampled at Plants D and E contain extraordinarily high levels of volatile and extractable organics when compared to other industries. These wastestreams are composed primarily of noncontact cooling water. Also contained in the discharges are sanitary wastes, boiler blowdown, and steam condensate, which are unlikely sources of the organic pollutants found in samples collected by EPA-ITD. Possible sources of contamination include illicit sewer connections, ground water infiltration, and poorly maintained cooling equipment.

In-plant control measures are more appropriate for controlling noncontact cooling water discharges than costly end-of-pipe technologies. These in-plant measures include routine equipment maintenance to prevent product leakage through condenser tubes, and replacement of pump packing materials with mechanical seals. Other control measures include segregation and separate treatment of sanitary wastewater, floor wash, spills, and contaminated runoff. No costs have been developed in this report to estimate the cost of implementing in-plant control measures. These costs would reflect plant size, plant age, and plant layout factors that are specific to the solvent recovery industry. This information is not currently available.

Cooling water treatment costs can be estimated, conservatively, by transferring technology demonstrated in the organic chemicals industry. Steam stripping has been shown to provide effective treatment for wastewaters and solvents (SAIC 1985). Of the 20 organic compounds listed in Table 5-5 as detected, 18 are volatile compounds. The remaining two, thioxanthone and tripropyleneglycol-methylether, are extractable compounds and less amenable to removal by stripping. However, these compounds were found in only one of the three samples. Therefore, for purposes of this report, steam stripping is judged to be the single, most effective technology suitable for the removal of 90 percent of organics found in solvent recycling wastewater.

The average solvent recycling plant discharges 11,000 gallons of cooling water on a continuous basis. In terms of 1985 dollars, an average plant that installed continuous mode treatment would incur an equipment cost of $250,000 and a land cost of 20 percent, or $50,000, for a total capital cost of $300,000. The annual operating expense would be $30,000 plus a $5,000 compliance monitoring cost, for a total operating expense of $35,000. Appendix C includes a detailed discussion of the basis for these costs.

7.3 ECONOMIC ASSESSMENT AND COST-EFFECTIVENESS

This subsection presents a preliminary economic assessment of possible regulations affecting the solvent recovery industry. The first part of the subsection presents operating and financial characteristics of the industry. This is followed by a discussion of the economic assessment of control options and the results of the analysis. The final part of this subsection provides an analysis of the cost-effectiveness of these possible regulations.

7.3.1 Economic Assessment

7.3.1.1 Treatment Technology and Model Plant

Because of the small amount of wastewater produced in solvent recovery, the most likely end-of-pipe control option is to contract haul the wastewater for treatment/disposal and recycle the cooling water after steam stripping. The costs developed for the model plant are based on this technology.

The model plant has the capacity to process 800,000 gallons of spent solvents annually. This includes 344,000 gallons of nonhalogenated solvents, 240,000 gallons of petroleum solvents, and 208,000 gallons of halogenated solvents. Using the percent recovery ratios shown in Table 7-2, this plant would produce a finished volume of 587,680 gallons of solvents, with a value of $1,150,931.

TABLE 7-2. ECONOMICS OF A SOLVENT RECOVERY MODEL PLANT (800,000 GALLONS PER YEAR CAPACITY)

Solvent Category	Spent Solvents Composition (%)	Spent Solvents Composition (gallons)	% Recovery	Finished Volume (gallons)	Solvents Price ($/gal)	Value ($)
Nonhalogenated	43	344,000	74	254,560	1.69	430,206
Petroleum	30	240,000	73	175,200	0.8	140,160
Halogenated	26	208,000	74	153,920	3.69	567,965
Other	1	8,000	50	4,000	3.15	12,600
Total	100	800,000		587,680		1,150,931

It costs $378,000 annually to implement the end-of-pipe control option described above for an 800,000 gallon solvent recovery plant, or about $0.47 per gallon of spent solvents processed. In terms of finished solvents, the control cost is about $0.64 per gallon.

One impact measure compares the annual control cost to the annual revenues of this plant. As shown in Table 7-3, control costs are equivalent to 33 percent of the value of the finished solvents. A second measure compares the annual control costs to the reclamation costs. Consulting engineering reports show that the costs of spent solvent reclamation ranges widely, varying between $0.20 and $1.55 per gallon (Engineering Science 1985; New England Congressional Institute 1986). Therefore, control costs are one-third to 2.5 times the reclamation costs. Since most recycling operations are conducted on a tolling basis, where a fee is charged for reclamation and the finished solvents are returned to the supplier, a good impact measure would be a comparison of the control costs to tolling fees. Agency data show that tolling fees range between $0.70 and $2.50 per gallon (ICF 1986). The treatment costs are calculated at $0.47 per gallon of solvent processed, which represents from 19 to 67 percent of the tolling fees. Given the wide variability in tolling fees and the uncertainty in treatment costs, no definitive conclusion can be made regarding the severity of the impacts.

7.3.2 Cost-Effectiveness

Cost-effectiveness is defined as the incremental annualized cost of a pollution control option in an industry or industry subcategory per incremental pound equivalent of pollutant removed by that control option. The analysis accounts for differences in toxicity among the pollutants with toxic weighing factors (TWF). The methodology for calculating cost effectiveness follows that used by EPA-ITD in studies of the Organic Chemicals, Plastics and Synthetic Fibers Industry. Because concentration data are not always available for many priority and non-priority hazardous pollutants, incremental removal may be underestimated for this preliminary cost-effectiveness calculation.

For solvent recyclers, two wastestreams are analyzed: process wastewater and cooling water. The control technologies for solvent recyclers are contract hauling the process wastewater to treatment/disposal and recycling the cooling water. In the United States, there are about 40 solvent recyclers discharging process wastewater; each facility generates 400 gallons per day. The annual process wastewater flow is 4.16 million gallons. Nationally, there are about 72 solvent recyclers generating cooling water with detectable levels of pollutants. The annual cooling water is 205.9 million gallons for these recyclers.

Table 7-4 shows the data used and the step-by-step cost-effectiveness calculations for process wastewater. The pounds equivalent (PE) removed for each pollutant is calculated on the

TABLE 7-3. ECONOMIC IMPACT MEASURES

	Total Amount	Cost Impact Measure
Total Cost of Treatment	$378,000	
Spent Solvent Processed	800,000 gal	$0.47 gal
Solvents Recovered	587,000 gal	$0.64/gal
Value of Recovered Solvents	$1,150,000	33% of value
Reclamation Costs	$0.20/gal to $1.55/gal	30 to 235% of reclamation costs
Tolling Fees	$0.70/gal to $2.50/gal	19 to 67% of tolling fees

7-4. COST-EFFECTIVENESS CALCULATION FOR SOLVENT RECYCLERS (ZERO DISCHARGE OF PROCESS WASTEWATER BY CONTRACT HAULING)

Number of plants discharging wastewater (N)	40
Wastewater flow (gpd) @ each plant (q)	400
Number of days/y in operation (d)	260
Annual flow (mg) for all plants = N x q x d	4.16

Pollutant Name	TWF	Raw Wastewater Probability	Raw Wastewater Concentration (ppm)	Annual PE
1,1,1-Trichloroethane	0.0003	1	82.1	0.85
1,2,4-Trichlorobenzene	0.02	0.33	248.0	56.79
1,2-Dichlorobenzene	0.017	0.33	3162.0	615.44
1,2-Diphenolhydrazine	1	0.33	238.3	2728.33
1,3-Dichlorobenzene	0.018	0.33	36.5	7.52
1,4-Dichlorobenzene	0.0213	0.33	76.6	18.68
2-Chlorophenol	0.215	0.33	44.5	109.54
Bis (2-ethylhexyl) phthalate	2.1876	0.33	1138.0	28502.54
Chloroform	2.952	0.33	40.5	1368.81
Di-N-Butyl Phthalate	0.0002	0.33	205.8	0.47
Di-N-Octyl Phthalate	0.812	0.33	260.0	2417.14
Fluoranthene	0.104	0.33	31.6	37.63
Fluorene	0.112	0.33	21.0	26.93
Methylene chloride	2.947	1	833.4	85210.48
Naphthalene	0.009	0.33	345.0	35.55
Phenathrene	0.281	0.33	46.8	15.06
Butyl benzyl phthalate	0.254	0.33	178.2	51.82
Phenol	0.0022	0.33	154.0	3.88
Pyrene	0.146	0.33	10.8	18.05
Tetrachloroethene	0.707	0.33	1350.0	10927.64
Toluene	0.0004	0.67	22.0	0.20
Trichloroethene	0.207	1	101.0	725.36
2,4-Dimethylphenol	0.0026	0.33	51.3	1.53
Ethylbenzene	0.004	0.67	1.44	0.13
Isophorone	0.00001	0.67	121.7	0.03
P-Cresol	0.1806	0.33	48.2	99.66
Sum (Organic) Conc. & Loading			8,849	132,980

7-4. COST-EFFECTIVENESS CALCULATION FOR SOLVENT RECYCLERS (ZERO DISCHARGE OF PROCESS WASTEWATER BY CONTRACT HAULING) (Continued)

Pollutant Name	TWF	Raw Wastewater Probability	Raw Wastewater Concentration (ppm)	Annual PE
Cadmium	5.09	1	2.1	362.02
Chromium	0.0267	1	3.5	3.24
Lead	1.75	1	16.6	1007.87
Nickel	0.114	1	7.7	30.45
Zinc	0.119	1	91.6	378.18
Antimony	0.00362	1	0.6	0.08
Arsenic	32.0295	1	0.07	77.79
Copper	0.467	1	5.1	82.63
Sum (Metals) Conc. & Loading			127	1,942
Sum (Organic & Metal) Conc. & Loading			8,976	134,922
Annualized cost ($)				10,608,000
CE ($/PE)				79
@ each plant: Capital cost ($)			20,000	
Annual hauling cost ($)			260,000	
Annualized cost ($)			265,200	

Data sources: Raw waste conc. (Tables 5-2 and 5-4).

basis of flow and concentration of that pollutant. Since the control option is contract hauling, raw waste loads are removed in their entirety. EPA estimated the concentration of each pollutant based on sample data. Method I concentrations are appropriate for the cost-effectiveness analysis and are used in this report. Total loading for each pollutant is calculated by applying the Method I concentrations and the proportion of sample plants with detectable levels of the pollutant (labeled probability in Table 7-4) to the total number of plants. For the 40 plants, the pound equivalents of pollutants removed are 134,922 and the annualized costs are $10,608,000. The cost-effectiveness of this option is $79 per pound equivalent.

Table 7-5 shows the data used and the step-by-step cost-effectiveness calculation for treating cooling water. Since the control technology is steam stripping, the analysis considers organic pollutants. The Agency has cooling water sample loadings data from two solvent recyclers, of which one has detectable concentrations and the other does not. The cost-effectiveness analysis assumes that one-half of the solvent recyclers discharging wastewater (72 plants) have levels of pollutants in their cooling water as detected at the sample plant. The total cooling water discharge for these 72 plants is 205.9 million gallons, and the pounds equivalent of pollutants removed is 79,355. With an annualized cost of $113,000 for each plant, or $8,136 million for 72 plants, the cost-effectiveness of this option is $102.53.

7.4 SUMMARY

The following summarizes the major points that were discussed in this section:

- Zero discharge of process wastewater by contract hauling and incineration is a model treatment system. A typical facility would incur a capital cost of $20,000 and an annual hauling cost of $260,000.

- If treatment of cooling water is needed, steam stripping technology is available that can be transferred to the solvent recycling industry. For treatment of cooling water, the average solvent recycling plant would incur a capital cost of $300,000 and an annual operating cost of $35,000.

- The annualized wastewater control cost is $0.47 per gallon of solvent processed, which represents from 19 to 67 percent of the tolling fees.

- The cost-effectiveness of treating the two types of wastewater is not significantly different, ranging from $79 to $102 per pound equivalent of pollutant removed.

TABLE 7-5. COST-EFFECTIVENESS CALCULATION FOR SOLVENT RECYCLING WASTEWATER TREATMENT (COOLING WATER BY STEAM STRIPPING)

Number of plants requiring steam stripping = one half of wet plants (N)	72
Cooling water (gpd) @ each plant (q)	11,000
Number of days/y in operation (d)	260
Annual cooling flow (mg) for all plants = N x q x d	205.92

Organic Pollutant Name	Waste Conc. (ppb)	TWF	Weighted Conc. (ppb)	Removal	Steam Stripping Efflu. Conc. (ppb)	Steam Stripping Wtd. Efflu. Conc. (ppb)
Acetone	415110	0	0	0.99	4151	0
Benzene	26130	0.848	22158	0.99	261	222
Methylene Chloride	5319	2.947	15675	0.99	53	157
1,1,2-Trichloroethane	2090	0.934	1952	0.99	21	20
1,1,2,2-Tetrachloroethane	2090	3.296	6889	0.99	21	69
Total Conc. (ppb)	450,739		46,674		4,507	467
Annual loading all plants	774,087		80,157		7,741	802
Incremental removal (PE) for all plants						79,355
Annualized cost ($)						8,136,000
CE ($/PE)						102
@ each plant: investment cost ($)					250,000	
land cost (20% of above) ($)					50,000	
O&M cost					30,000	
monitoring cost ($/y)					5,000	
annualized cost ($)					113,000	

Data sources: Table 5-5 and SAIC, 1987f.

8. ENVIRONMENTAL ASSESSMENT

The purpose of this section is to present the results of an environmental assessment. The methodology used to estimate human health and aquatic life water quality impacts is described and results are discussed. Non-water quality impacts on emissions to the air, solid waste generation, and energy usage are also discussed.

8.1 METHODOLOGY USED TO ESTIMATE HUMAN HEALTH AND AQUATIC LIFE WATER QUALITY IMPACTS

An environmental assessment of water quality impacts was performed for both direct and indirect wastewater dischargers. Average plant raw waste concentrations and discharge flows for this industry/subcategory were used to project impacts on receiving streams. Water quality impacts for treated effluents were not performed because of the lack of pollutant-specific data.

8.1.1 Direct Discharge Analysis

The following analyses were performed for direct dischargers: (1) criteria comparisons, (2) stream flows with potential impacts, and (3) loading comparisons. The raw waste concentrations from wastestreams were compared to available water quality criteria (acute and chronic aquatic life criteria/ toxicity levels); human health criteria (ingesting water and organisms), including criteria for carcinogenicity protection or toxicity protection; and existing or proposed drinking water standards. A value greater than one indicates a criteria exceedance. The numerical values associated with these exceedances (exceedance factors) represent instream dilutions needed to eliminate projected water quality impacts.

Because actual receiving streams flow data were not available for this industry/subcategory, the stream flows with potential impacts also were projected using stream dilution factors and average plant flows.

Specific pollutant loadings were calculated based on the raw waste concentrations and total industry/subcategory flow and summed. The pollutant loadings were grouped into four categories: (1) total priority organics, (2) total non-priority organics, (3) total priority inorganics, and (4) total non-priority inorganics. The total priority organics and inorganics were then compared to the total raw waste pollutant loadings from regulated best available technology (BAT) industries to evaluate the significance of pollutant loadings from the industry/subcategory considered in this document.

8.1.2 Indirect Discharge Analysis

The following analyses were performed for indirect dischargers: (1) criteria comparisons using a publicly-owned

treatment works (POTW) model and stream dilution analysis, (2) impacts to POTWs, and (3) loading comparisons.

A simplified POTW model and stream dilution analysis were performed to project receiving stream impacts from indirect dischargers. Actual receiving stream flow and POTW flow data were not available for this industry subcategory. In order to project receiving stream impacts, a statistical analysis was performed on the Environmental Protection Agency's (EPA's) In-House Software (IHS) Industrial Facilities Discharge File and GAGE File to determine a POTW plant flow and a POTW receiving stream flow for use in the analyses. The 25th, 50th, and 75th percentile flows for POTWs with industrial indirect dischargers were 0.35, 1.1, and 3.0 million gallons per day (MGD), respectively. For this study, a 1.0 MGD plant flow is used. This is approximately the 50th percentile (median) flow and representative of the typical POTW plant flow. Twenty-one POTWs receiving industrial discharge had a plant flow of 1.1 MGD. The median receiving stream flow for the 21 POTWs was 12 MGD at low flow conditions and was used in the analysis to determine the diluted POTW effluent concentration.

Potential water quality impacts on receiving streams were determined using criteria comparisons. The POTW effluent pollutant concentrations calculated using Equation 1 were compared to acute aquatic criteria/toxicity levels to determine impacts in the mixing zone.

Equation 1:

$$\text{POTW Effluent } (\mu g/l) = \text{POTW Influent } (\mu g/l) \times (1 - \text{Treatment Removal Efficiency})$$

A calculated instream diluted POTW effluent concentration using Equation 2 was compared to chronic aquatic life criteria/toxicity levels, human health criteria, and drinking water standards.

Equation 2:

$$\text{In-Stream Diluted POTW Effluent}(\mu g/l) = \frac{\text{POTW Effluent } (\mu g/l) \times \text{POTW Flow (MGD)}}{\text{POTW Receiving Stream Flow (MGD)}}$$

Impacts on POTW operations were calculated in terms of inhibition of POTW processes and contamination of POTW sludges. Inhibition of POTW operations was determined by comparing POTW influent levels (Equation 3) with inhibition levels, when available.

Equation 3:

$$\text{POTW Influent} = \text{Average Plant Concentration } (\mu g/l) \times \frac{\text{Total Industry Flow (MGD)}}{\text{POTW Flow (MGD)}}$$

Contamination of sludge (thereby limiting its use) was evaluated by comparing projected pollutant concentrations in sludge (Equation 4) with sludge contamination levels, when available.

Equation 4:

Pollutant Concentration in Sludge (mg/kg) =
POTW Influent (μg/l) x Partition Factor x
Tmt. Removal Efficiency x 5.96 x Conversion Factors

The partition factor is a measure of the tendency for the pollutant to partition in sludge when it is removed from wastewater. For metals, this factor was assumed to be one. For predicting sludge generation, the model assumed the Metcalf and Eddy rule of thumb that 1,400 pounds of sludge is generated for every million gallons of wastewater processed which results in a sludge generation factor of 5.96.

To evaluate the significance of pollutant loadings from untreated indirect discharges, loading comparisons from indirect dischargers were performed using the same approach as with the direct dischargers. The total raw waste priority pollutant organic and inorganic loadings were compared to the total raw waste pollutant loadings from regulated industries with Pretreatment Standards for Existing Sources (PSES).

8.2 RESULTS OF ENVIRONMENTAL ASSESSMENT

8.2.1 Process Wastewater

Discharge flows of process wastewater are very small, averaging 400 gpd per plant. Total direct discharge flow is only 4,000 gpd, and total indirect discharge flow only 12,000 gpd.

Because of very high concentrations for the majority of detected pollutants, projected water quality impacts from direct discharges of untreated process wastes are very significant for small to medium receiving streams (with stream flows up to 2,000 MGD), even at small average plant discharge flows (400 gpd). Of 69 detected pollutants, 57 were at levels that may be harmful to human health and/or aquatic life:

- 34 pollutants (including 10 carcinogens) have projected human health impacts for streams with less than 2,000 MGD flow;
- 40 pollutants have projected short-term (acute) aquatic life impacts in mixing zones of receiving streams with exceedance factors ranging from 1 to 2,000;
- 51 pollutants have projected long-term (chronic) aquatic life impacts for streams with less that 150 MGD flow; and

- 17 pollutants have projected drinking water impacts, but only for very small streams (less than 2 MGD flow).

Untreated direct discharges of the carcinogen 1,2-diphenylhydrazine alone would require more than 2,000 MGD receiving stream flow to dilute the discharge concentration below levels harmful to human health. To eliminate the aquatic life impacts of bis(2-ethylhexyl)phthalate, a receiving stream flow of more than 150 MGD is required. Potential drinking water impacts from discharge of 1,2-dichlorobenzene are projected only for small streams, with less than 2 MGD flow.

Indirect discharges of untreated process wastewater, based on projected discharge to a model 1 MGD POTW (representing the median size POTW with indirect industrial dischargers), are expected to inhibit POTW treatment for one pollutant but not cause any sludge contamination; however, process wastes may cause POTWs to exceed human health criteria in receiving streams for six pollutants (all carcinogens), and chronic aquatic life criteria for one pollutant.

The control technology for solvent recycler process wastewater is contract hauling to a treatment/disposal facility (zero discharge); therefore, the environmental impacts for treated effluents for direct and indirect dischargers were not projected.

Pollutant Loadings (lbs/day)

	Raw Wastewater	Treated Wastewater
Priority organics:	288	864
Non-priority organics:	476	1,429
Priority inorganics:	4	12
Non-priority inorganics:	184	493
	932	2,798

Total loadings of priority pollutant inorganics from untreated process wastewater (e.g., 4 lbs/day from direct and 12 lbs/day from indirect dischargers) are less than the lowest raw waste total priority pollutant inorganic loadings from regulated BAT/PSES industries. Total raw waste loadings of priority organics from both direct and indirect discharges (e.g., 288 lbs/day and 864 lbs/day, respectively) are more significant (comparable to raw waste priority pollutant organics loadings form the raw waste regulated industries ranked in the lower third of loading rankings).

8.2.2 Contaminated Cooling Water

The contaminated cooling water discharge flows average 11,000 gpd per plant. The total direct discharge flow is about 0.4 MGD, and total indirect discharge flow about 1.2 MGD.

Untreated Cooling Water

Potential water quality impacts from direct discharge of untreated contaminated cooling water were projected for small streams with less than 300 MGD flow. Of 25 detected pollutants, 13 were at levels that may be harmful to human health and/or aquatic life:

- 9 pollutants (including 6 carcinogens) have projected human health impacts for streams with less than 300 MGD flow;
- 6 pollutants have projected short-term (acute) aquatic life impacts in mixing zones of receiving streams with exceedance factors as high as 46;
- 9 pollutants have projected long-term (chronic) aquatic life impacts for streams with less that 9 MGD flow; and
- 9 pollutants have projected drinking water impacts on streams with less than 30 MGD flow.

Direct discharge of the carcinogen, methylene chloride, alone would require more than 300 MGD stream flow to dilute the discharge concentration below levels harmful to human health, and more than a 30 MGD flow is needed to eliminate potential drinking water impacts from the carcinogen benzene. Aquatic life impacts were projected for streams up to 9 MGD flow (for acetone).

Potential water quality and POTW impacts from indirect discharges of untreated contaminated cooling water (projected based on a model 1 MGD POTW) are not significant. No detrimental impacts on POTWs were projected. Only one pollutant (the carcinogen methylene chloride) has the potential to exceed criteria for human health in surface waters receiving indirect discharges through POTWs.

Treated Cooling Water

The control technology for contaminated cooling water is steam stripping with an assumed 99 percent removal rate for all pollutants.

Potential water quality impacts from direct discharge of treated cooling water were projected for only very small streams with less than 3 MGD flow. Of 25 detected pollutants, 9 were at levels that may be harmful to human health and/or aquatic life:

- 4 pollutants (including 3 carcinogens) have projected human health impacts for streams with less than 3 MGD flow;
- No pollutants have projected to have short-term (acute) aquatic life impacts;

- 4 pollutants have projected long-term (chronic) aquatic life impacts for streams with less that 0.1 MGD flow; and

- 2 pollutants may have drinking water impacts on streams with less than 0.3 MGD flow.

Potential water quality and POTW impacts from indirect discharges treated cooling water (projected based on a model 1 MGD POTW) are insignificant. No detrimental impacts on POTWs or receiving streams are projected.

Pollutant Loadings (lbs/day)

	Untreated Cooling Water	Treated Cooling Water
Direct Dischargers		
Priority organics:	78	0.8
Non-priority organics:	1,373	13.7
Priority inorganics:	14	0.2
Non-priority inorganics:	234	2.3
	1,699	17.0

	Untreated Cooling Water	Treated Cooling Water
Indirect Dischargers		
Priority organics:	232	2.3
Non-priority organics:	4,080	40.8
Priority inorganics:	42	0.4
Non-priority inorganics:	694	6.9
	5,048	50.4

Total loadings of priority pollutant inorganics from direct and indirect discharge of untreated contaminated cooling water (e.g., 14 lbs/day and 42 lbs/day, respectively) are less than the lowest raw waste priority pollutant inorganic loadings from regulated BAT/PSES industries. The total untreated loadings of priority pollutant organics from both direct and indirect discharges (e.g., 78 lbs/day and 232 lbs/day, respectively) are also relatively low, comparable to the raw waste priority organics loadings for regulated industries ranked in the lower third.

Total loadings of priority pollutant inorganics from treated cooling water are: 0.2 lbs/day for directs; and 0.4 lbs/day for indirects. Total loadings of priority pollutant organics from treated cooling water are: 0.8 lbs/day for directs; and 2.3 lbs/day for indirects. These are less than the lowest treated (BAT/PSES) loadings from regulated industries.

8.3 NON-WATER QUALITY ENVIRONMENTAL IMPACTS

The elimination or reduction of one form of pollution may create or aggravate other environmental problems. Therefore, Sections 304(b) and 306 of the CWA require EPA to consider non-water quality environmental impacts of certain regulations. In compliance with these provisions, EPA has considered the effect of possible regulations on air pollution, solid waste generation, and energy consumption. The non-water quality environmental impacts associated with this regulation are described below.

8.3.1 Air Pollution

Implementation of the model cost technologies would result in significant reductions in air emissions from present rates. This conclusion is based on the prevailing absence of end-of-pipe treatment technologies in the solvent recycling industry. Contract hauling and incineration of process wastewater and steam stripping of contaminated cooling water would significantly reduce volatile organic carbon (VOC) emissions to the atmosphere. Data are not available, however, to accurately estimate the VOC mass potentially reduced if model control technologies were implemented.

8.3.2 Solid Waste

EPA considered the effect that implementation of the model control technology could have on the production of solid waste, including hazardous waste defined under Section 3001 of the Resource Conservation and Recovery Act (RCRA). EPA estimates that increases in total solid waste and hazardous waste would be insignificant compared to current levels. The net residual solid waste from contract hauling and incineration of process wastewater, in the form of ash, will be negligible. Residuals from steam stripping would be in the form of recyclable solvents.

8.3.3 Energy Requirements

Implementation of the model cost technologies could increase energy consumption significantly over present industry use. The model technologies, contract hauling and incineration of process wastewater and steam stripping of cooling water, are similar to the technologies used to recover solvents with respect to energy requirements. Energy consumption could double over current usage (SAIC 1987f). The estimated increased energy consumption is 81,000 barrels of No. 2 fuel per year. However, most plants are likely to implement cost-effective Best Management Practices (BMPs) to control pollutants in cooling water discharges. BMPs are less costly and often more practical than end-of-pipe control technologies such as steam stripping.

8.4 SUMMARY

The following list summarizes the major points that were discussed in this section:

- Total loadings of priority pollutant inorganics from untreated process wastewater are less than the lowest raw waste total inorganics loadings from regulated BAT/PSES industries. Total loadings of priority pollutant organics are more significant and rank in the lower third of the loadings rankings.

- Total loadings of priority pollutant inorganics and organics from untreated cooling and miscellaneous wastewater are low relative to the lowest raw waste loadings from the regulated BAT/PSES industries.

- Implementation of the model cost technologies would result in significant reductions in air emissions, an insignificant increase in solid and hazardous waste, and a doubling of energy consumption.

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